N68-19334

DEPLOYABLE LARGE AREA

SOLAR CELL ARRAY TESTING

RYAN REPORT NO. 20867-1

QUARTERLY REPORT

15 JANUARY 1968

JPL CONTRACT 951107

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology as sponsored by the National Aeronautics and Space Administration under Contract NAS-7-100.

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ABSTRACT

This report covers Part 1 of the Phase IV program for nondestructive dynamic testing and evaluation of the prototype deployable solar array support structure manufactured under JPL Contract 951107.

The work accomplished during the period covered by this report consists of a test plan and procedure, design layout and detail design of the modular solar cell installation, the 0.2g cruise maneuver acceleration test, application of active and dummy solar cells to the panel substrate, and final assembly of the solar array for testing. Also accomplished were design and fabrication of special support fixtures, vibration fixtures, and solar cell test equipment. Process development samples were prepared and a thermal-vacuum test was conducted to evaluate the effect of process variables on low temperature deployment of the solar array panel.

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LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

This progress report is submitted under JPL Contract 951107 and covers Phase IV testing and evaluation of a prototype large area solar array structure.

This work is an extension of the Phase I, II and III activities of the contract which have been previously reported in Ryan Reports 20869-1, 20869-2, and 20869-3 (references 1, 2 and 3).

The period of performance covered in this report is from start of Phase IV activity on 5 June 1967 through 31 October 1967.

The reporting period has been extended in order to cover the cruise maneuver test and assembly of the solar cell array.

2.0 TECHNICAL DISCUSSION

The solar cell array support structure designed and fabricated in earlier phases of this contract is suitable for a Mars or Venus mission, i.e., launch and encounter, using chemical systems and an Atlas/Centaur launch vehicle.

The purpose of this test program is to evaluate the structural integrity and electrical characteristics of the solar array assembly when subjected to the most critical launch and environmental conditions anticipated during a hypothetical mission to Mars or Venus.

Previous design and fabrication activity has been limited to the deployable array structure. In order to conduct the test program it has been necessary to complete the design of the solar cell array installation and apply active and simulated solar cells to the panel substrate.

2.1 TEST PLAN AND PROCEDURES

2.1.1 Test Plan

A detailed test plan was prepared to establish the criteria for evaluation of the solar array structure. The plan and procedures are contained in Report 20865-1, Test Plan and Procedures for Phase IV Nondestructive Testing and Evaluation of the Prototype Deployable Solar Array Structure Manufactured Under Contract 951107 (reference 4).

The tests are designed to:

a. Assure satisfactory operation of the deploying beam and mechanism and solar cells in a space environment with thermal environment at the upper limit comparable to the Mariner 67 Venus Mission, ($260MW/CM^2$).

b. Accumulate temperature gradients and temperatures at selected locations on the beams and substrate for correlation with theoretical values.

c. Determine if the solar cell protection pads are sufficient to prevent launch vibration damage to the solar cells and electrical wiring.

d. Compare drive torque requirements, under simulated vacuum and IR flux environment, with sea level requirements.

e. Assure that the deployable beams will carry the steady state acceleration induced to the deployed array during cruise maneuver.

f. Assure that a sterilization thermal environment will not have adverse effects on the electrical or structural characteristics.

2.1.2 Test Procedures

The tests are based on JPL design criteria for the deployable solar array (see reference 2, Ryan Report No. 20869-2, 5 May 1966) with modification of the thermal vacuum cycling criteria so that it is comparable with both a Venus mission and a Mars mission.

The tests consist of the following:

a. Simulation of 0.2g cruise maneuver.

b. Deployment cycle effects on solar cells in a 1.0g ambient environment.

c. Launch vibration environment consisting of sinusoidal vibration at 1.6g rms from 6 to 20 Hz and 4.0g rms from 20 to 200 Hz; also random vibration at $0.1g^2$/Hz and $0.2g^2$/Hz from 200 to 2000 Hz each for 180 sec. Sinusoidal and random environment induced independently.

d. Deployed dynamic characteristics to determine the beam first cantilever bending mode, panel first torsion mode, and substrate first mode.

e. Acoustic test simulating launch environment for the Mariner 69 booster.

f. Thermal vacuum test consisting of two deployment and retraction cycles. The first cycle simulates a condition in which the shroud is ejected while the spacecraft is in orbit in earth shadow. The panels deploy while the spacecraft is still in earth shadow, then the spacecraft moves from shadow into sunlight and proceeds on a Mars mission. Panels retract and deploy somewhere enroute. (Solar flux is assumed, conservatively, equal to that near earth.)

   The second cycle simulates a similar orbit and deployment with the spacecraft in earth orbit with the panels deploying in earth shadow. Then the spacecraft proceeds on a Venus mission. The panels retract and deploy somewhere enroute. (Solar flux is assumed, conservatively, equal to that near Venus.)

g. Sterilization Heat Flux simulation consisting of three cycles of 36 hours at 295°F in dry nitrogen.

h. Repeat launch sinusoidal vibration in the most critical axes, and electrical performance measurements to evaluate effects of sterilization thermal environment.

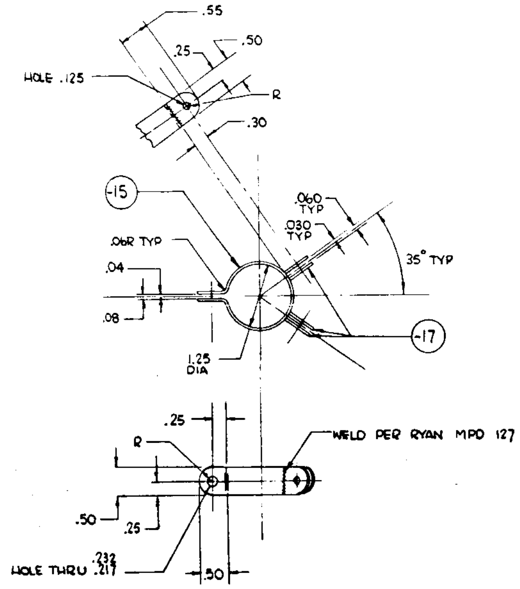
2.2 DESIGN DISCUSSION

The design tasks completed in this period include definition of the active and simulated solar cell installation, design of a deployment support fixture, a design of vibration test fixtures, and a solar cell array electrical test console. The solar array structure is shown in Figures 1 and 2. In the original design, the four substrate modules provided an area of 51 square feet, with an additional 6 square feet available for mounting cells by extending the substrate inboard to meet the storage drum.

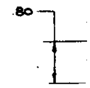
The inbord substrate module was redesigned to attach to the wrap drum and provide 57 square feet total area. It was then possible to set back the outer boundary of the solar cell area (50 square feet) by 13 inches from the end of the panel. This change allowed all solar cells to be wrapped on the cylindrical surface to the storage drum.

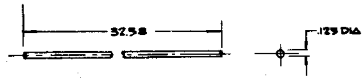
A new end plate stiffening bracket assembly was designed to replace the hat section stiffener shown in Figure 1, which joined the two end assemblies across the extended solar panel surface. This bracket detail is shown on E.O.366013 to drawing No. 208V006. (See Appendix).

Figure 3 shows the installation of solar cells on the panel substrates. Fourteen solar cell submodules are arranged in pairs at seven locations on the panels. The active cell locations were chosen to provide cells at the most critical areas during launch and deployment testing. The five center groups provide a stack of five layers at the drum center where maximum launch loads occur. The other two cell groups are located at areas of maximum and minimum substrate distortion previously observed in deployment cycling.

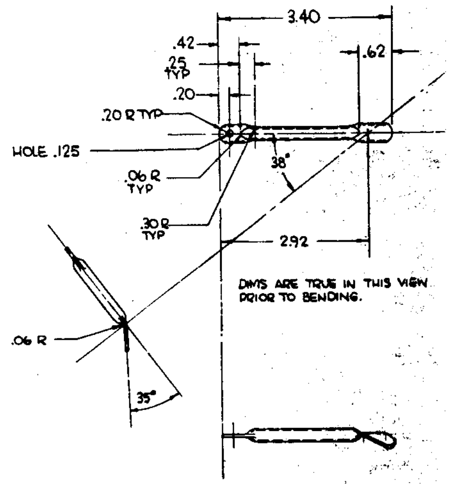


ASSY -13

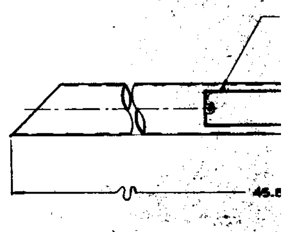




DETAIL -11 HINGE PIN



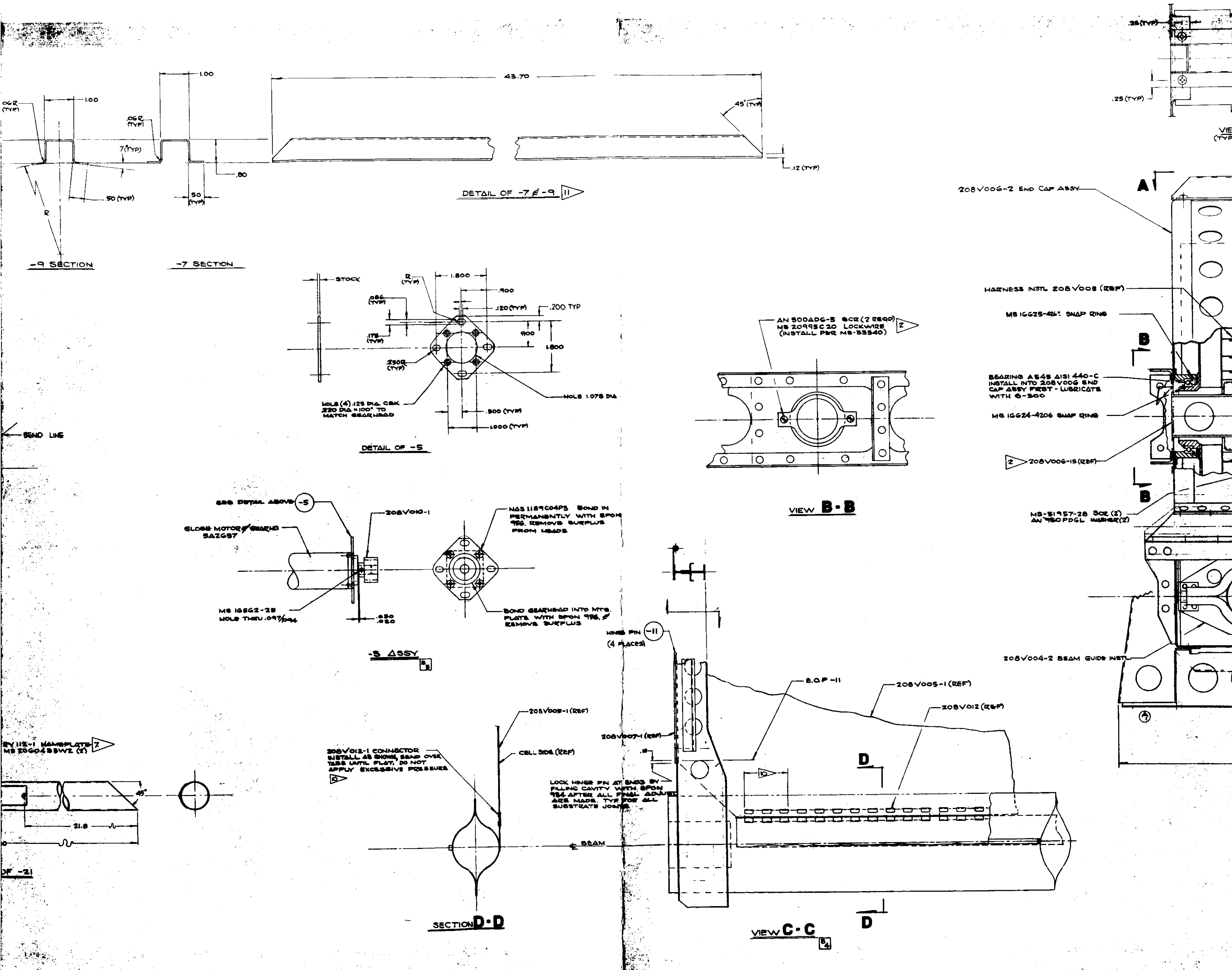
DETAIL OF -19 -20



DETAIL-

6-1

FOLDOUT FRAME



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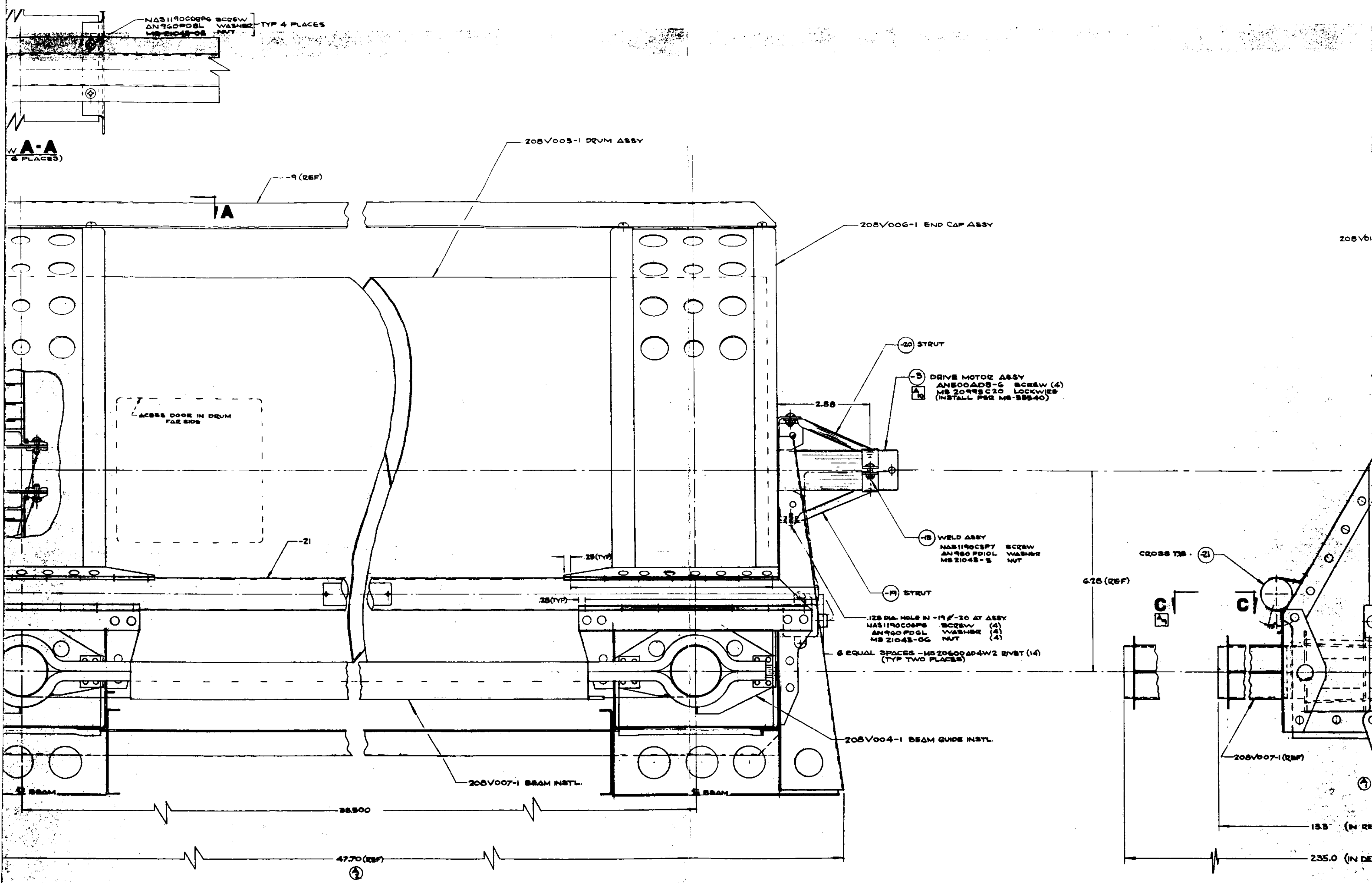
FOLDOUT FRAME 2

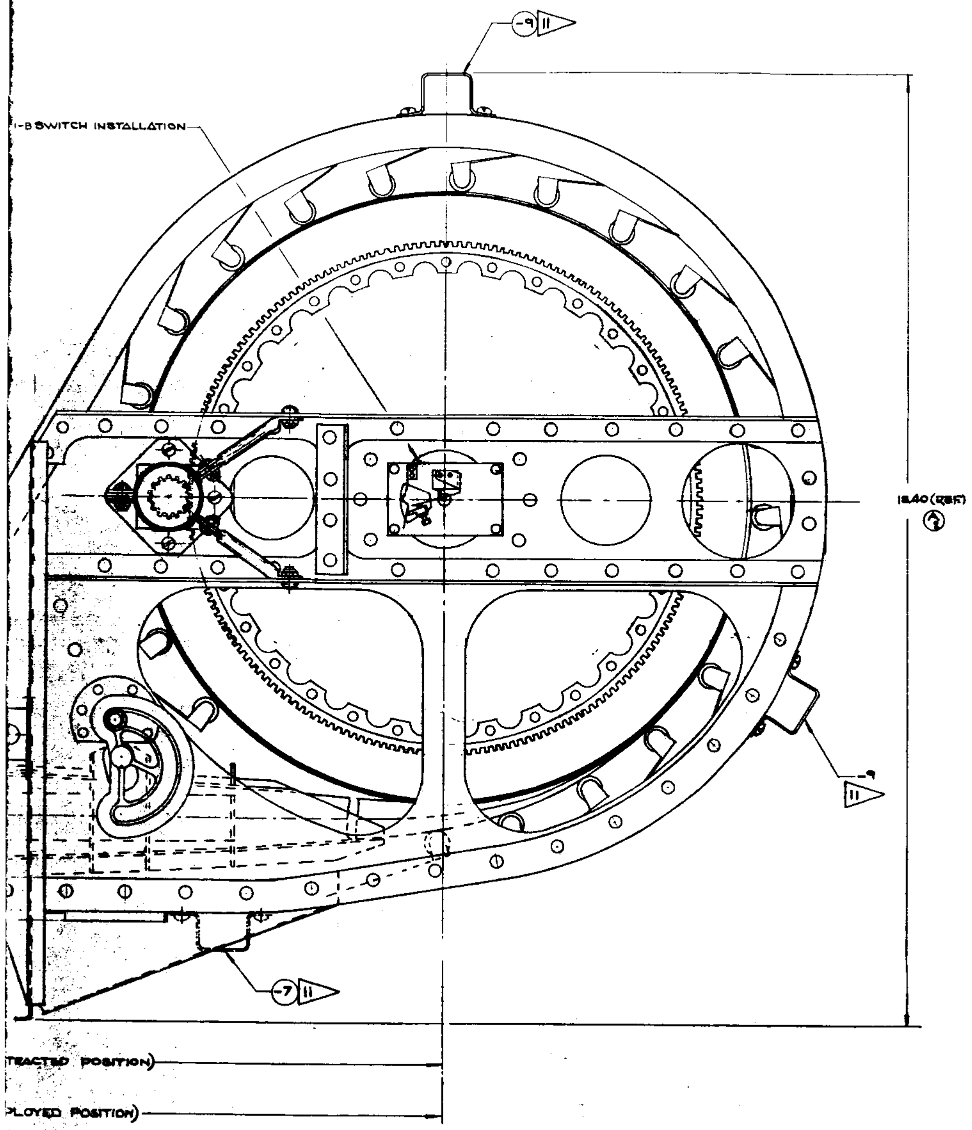


-1 DEPLOVABLE SOLAR PANEL ASSEMBLY

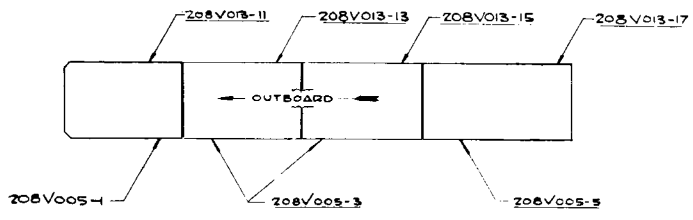
FOLDOUT FRAME

3

FOLDOUT FRAME



DRUM ASSY SHOWN IN DEPLOYED POSITION



VIEW SHOWING RELATIVE POSITIONS OF SUBSTRATE ASSEMBLIES IN DEPLOYED CONDITION

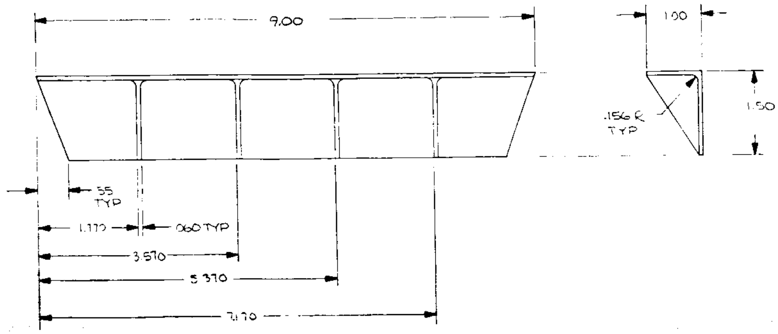
NOTES:

1. MAY BE PURCHASED FROM GLOBE INDUSTRIES-DAYTON 4, OHIO
2. SEE 208V008 FOR INSTALLATION INSTRUCTIONS.
3. ALL PROCESSES TO BE IN ACCORD WITH RYAN SPEC. 208S002
4. HEAT TREAT TO T-6 AFTER FORMING
5. ANODIZE WITH DOW 17 TYPE I PER MPD-102
6. SHELL CHEMICAL AND PAINT CO., PITTSBURG, CALIF.
7. ADD THE FOLLOWING INFORMATION TO NAMEPLATE:
   NAME OF PART: DEPLOYABLE SOLAR PANEL
   SERIAL NO.: 1, 2, 3, 4 (AS APPLICABLE)
   PART NO.: 208V001
   CONTRACT NO.: NAS 7-100/951107
   MARK OUT 'FSN'
8. THIS PART TO BE VERIFIED FOR AVAILABILITY. INFORMATION TO BE SUPPLIED AT A LATER DATE.
9. CHEM MILL WALL THICKNESS TO .042 -.044 PER MPD 122. CHEM MILL O/D OF TUBE ONLY.
10. 208V012-1 INSERTS TO BE INSTALLED IN SUCESSION WITH THE LAST ONE TO BE TRIMMED TO FIT REMAINING HOLES BETWEEN SUBSTRATE & BEAM. ONE (1) INSERT REQUIRED TO TRIM EACH SUBSTRATE SECTION.
11. -7 & -9 ARE USED TO FACILITATE ASSY. & TRANSPORTATION ONLY. REMOVE FOR FLIGHT & TEST
12. -100 TEST CONFIG. ONLY-REF PHASE IV CONTRACT 951107

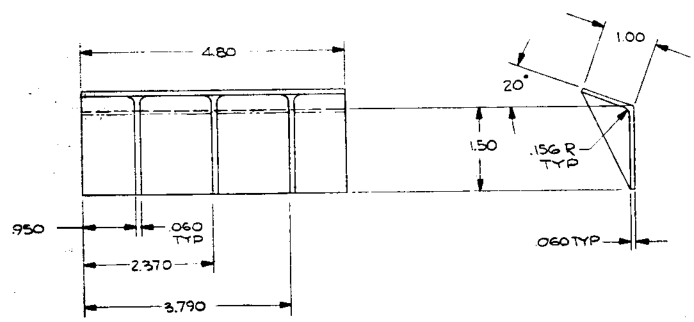
Figure 1. Deployable Solar Panel Assembly

4 FOLDOUT FRAME

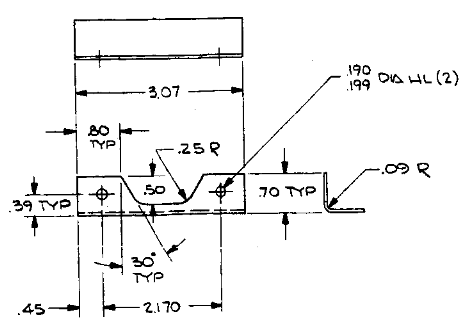
FOLDOUT FRAME



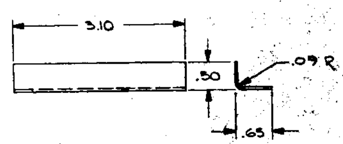
DETAIL -15



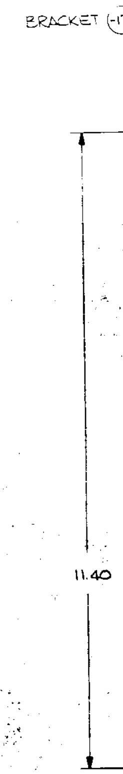
DETAIL -17



DETAIL -21

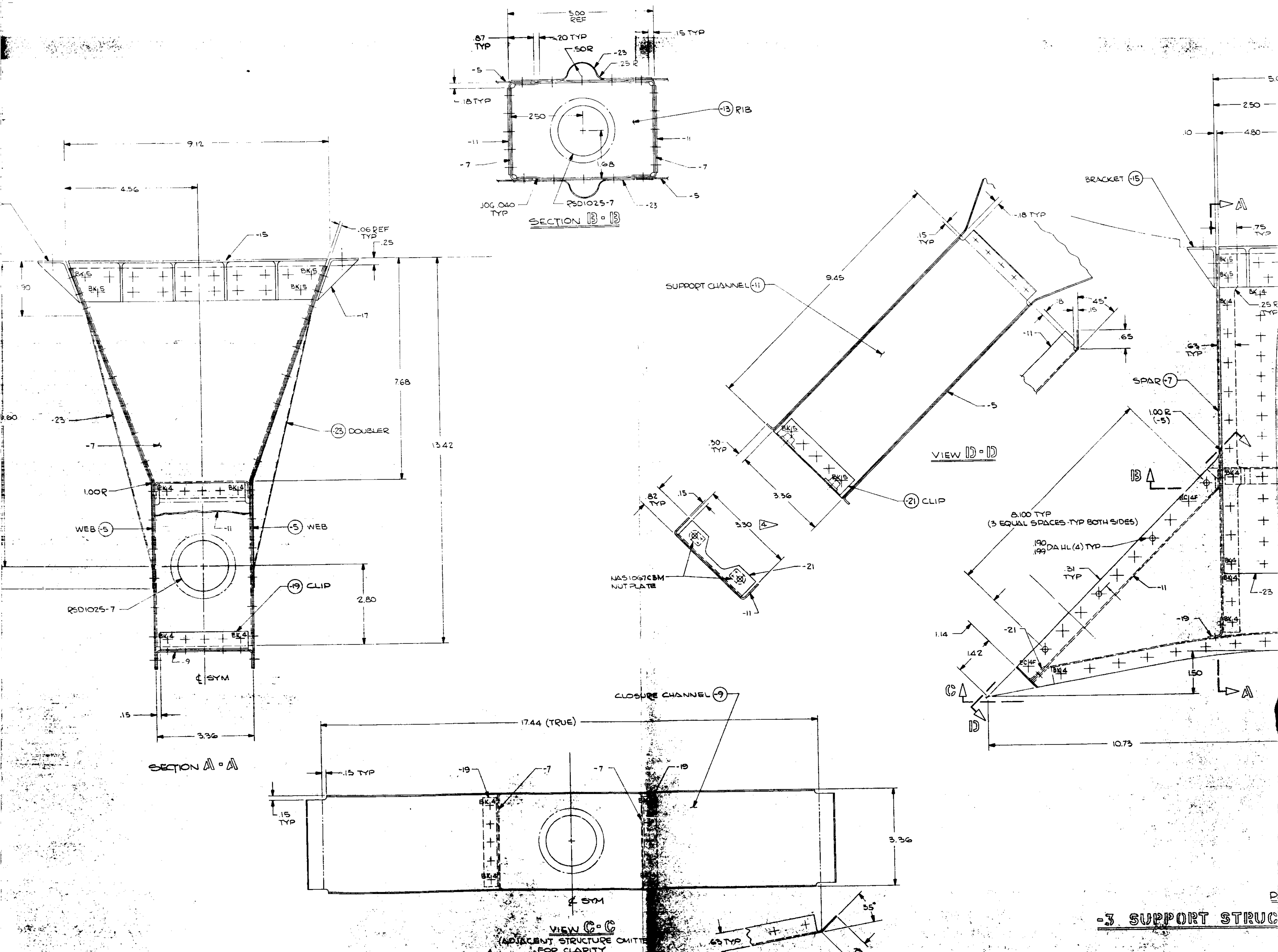


DETAIL -19



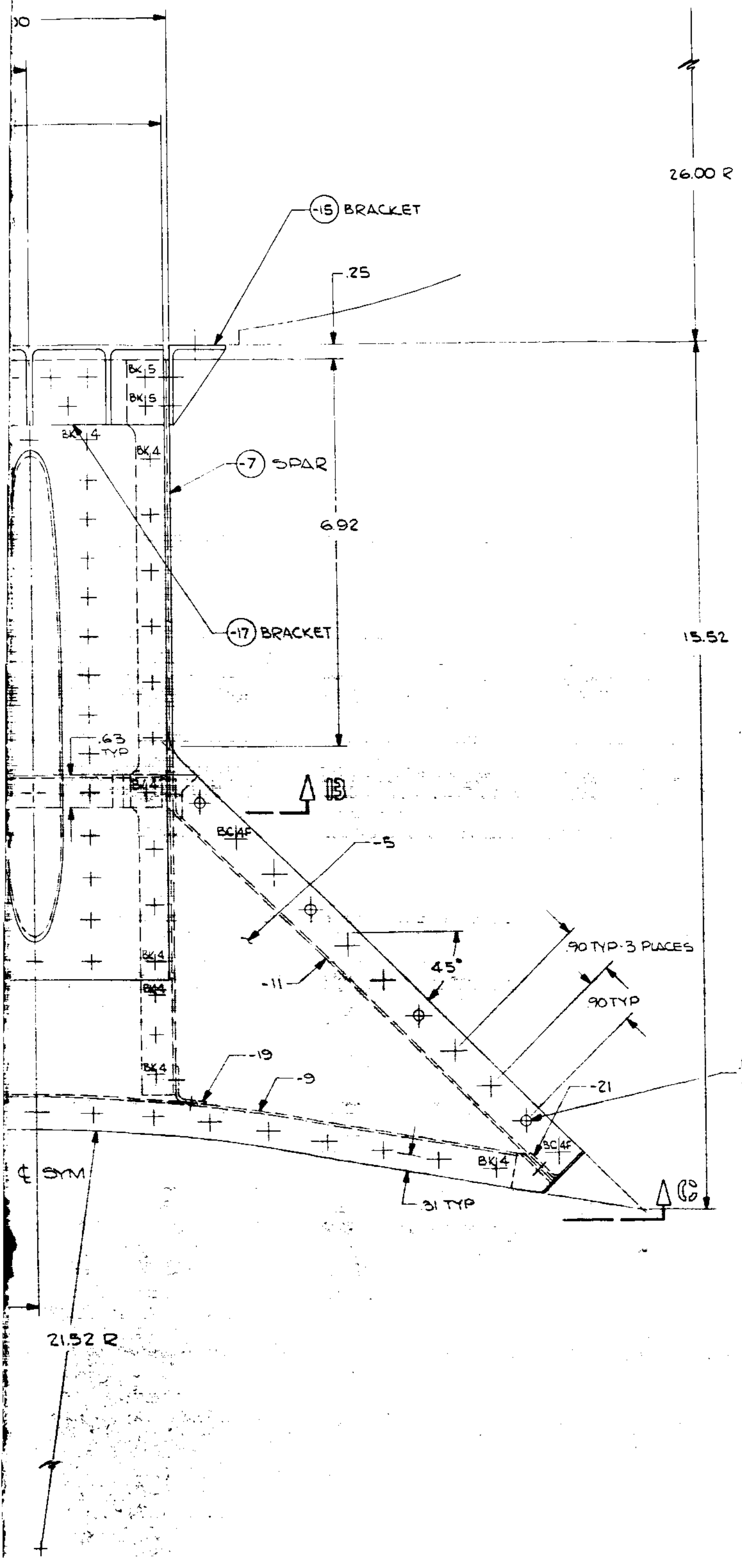
FOLDOUT FRAME

7-1



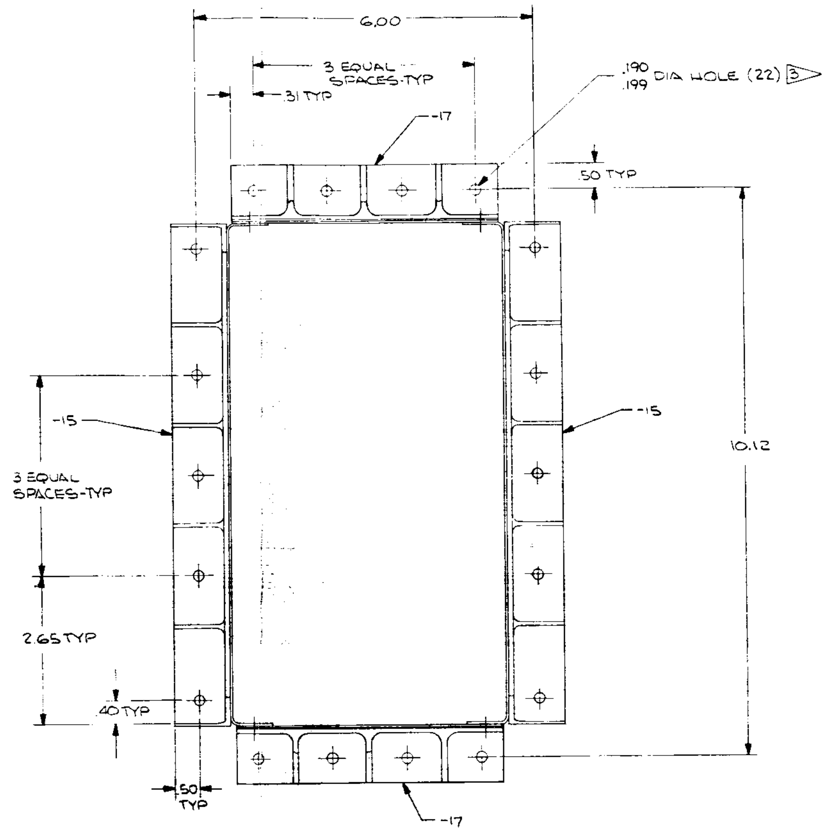
FOLDOUT FRAME

FOLDOUT FRAME

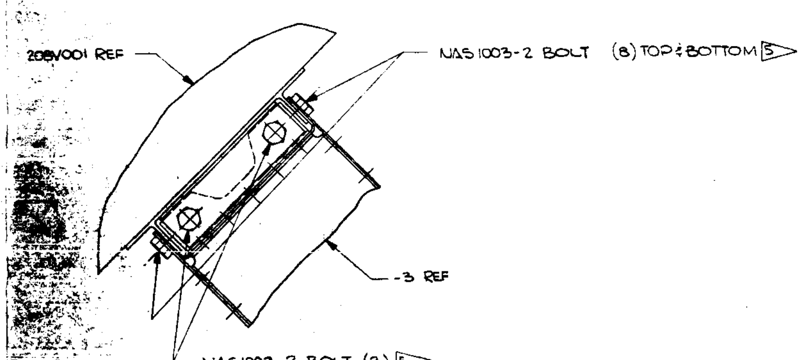


AN VIEW

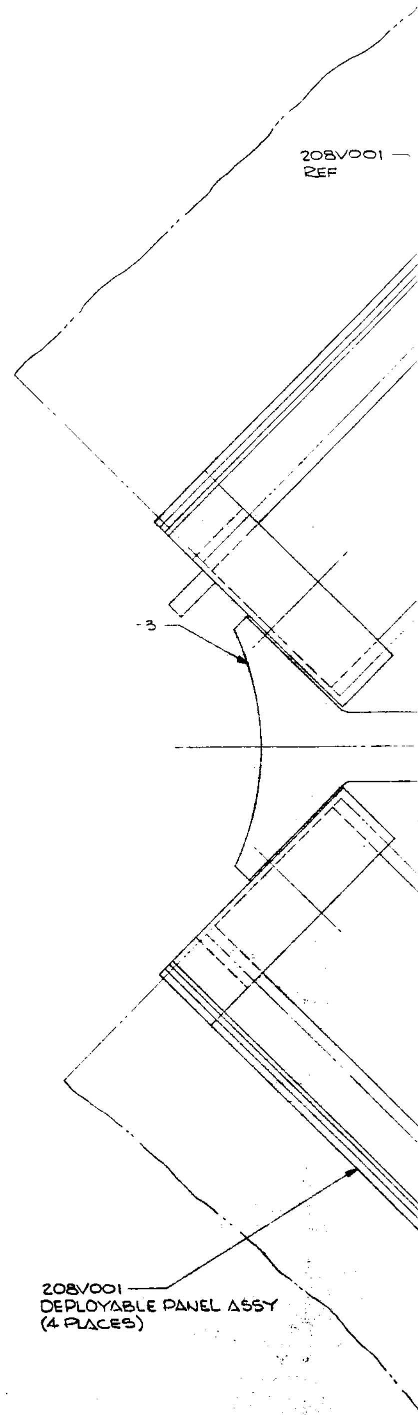
TURE ASSEMBLY



SECTION E-E
(SHOWING ATTACH PATTERN -1 INSTL TO VEHICLE-TYP 4 PLACES)



SECTION F-F
(TYP 8 PLACES)

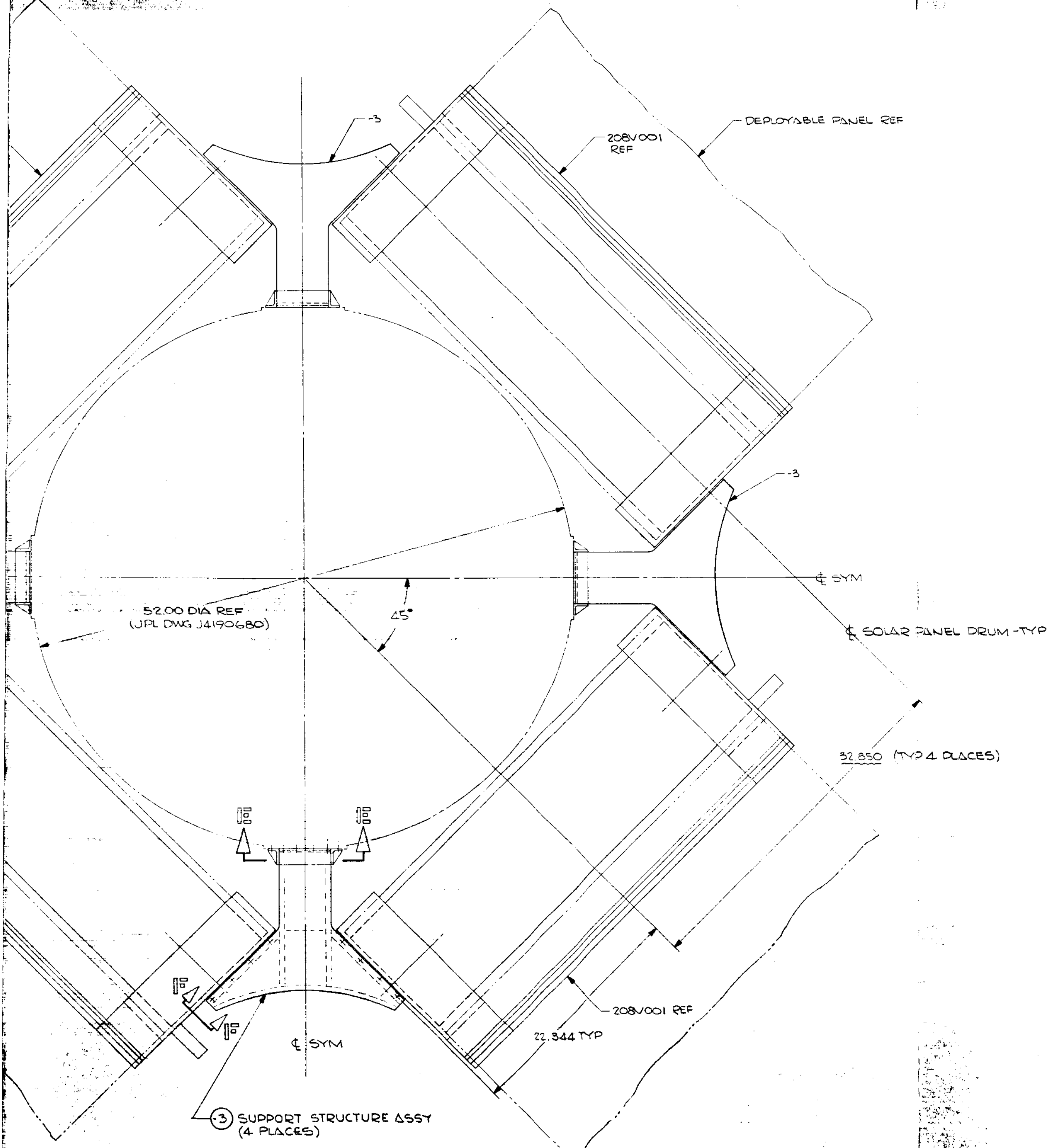


3

FOLDOUT FRAME

FOLDOUT FRAME

4



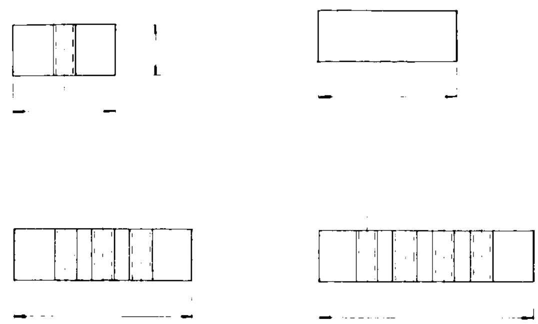
-1 SOLAR ARRAY INSTL

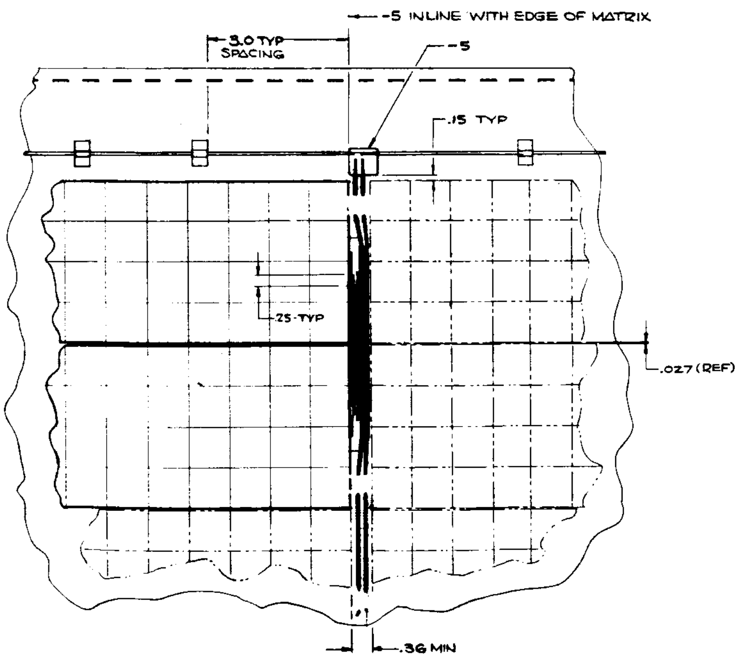
SCALE 1/4

NOTES:

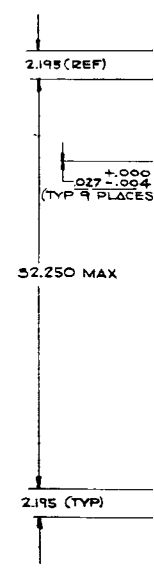
1. EDGE DISTANCE FOR NO. 4 RIVETS TO BE .25 EXCEPT AS SHOWN.
2. EDGE DISTANCE FOR NO. 5 RIVETS TO BE .31 EXCEPT AS SHOWN.
3. ATTACHMENT HARDWARE FOR -1 INSTL TO BE FURNISHED BY CUSTOMER.
4. MATING DIMENSION $^{+.01}_{-.00}$. TO ALLOW FITNESS OVER ATTACH FLANGES OF 208V001.
5. TORQUE TO 20-25 IN. LBS.
6. BEND RADII TO BE .09.
7. RELIEF RADII TO BE .12.
8. ALLOWABLE MACHINE MISMATCH FROM DIMENSIONS INDICATED TO BE -.000 TO +.030.
9. SHEET STOCK TOL $^{+.00}_{-STD}$.
10. ALL PROCESSES TO BE IN ACCORD WITH RYAN SPEC 2085002
11. ANODIZE ALL DETAILS WITH DOW 17 TYPE I PER MPD 102
12. REMOVE 208V001-7 & -9 CHANNELS ON INSTL.

Figure [illegible]. Solar Array Installation



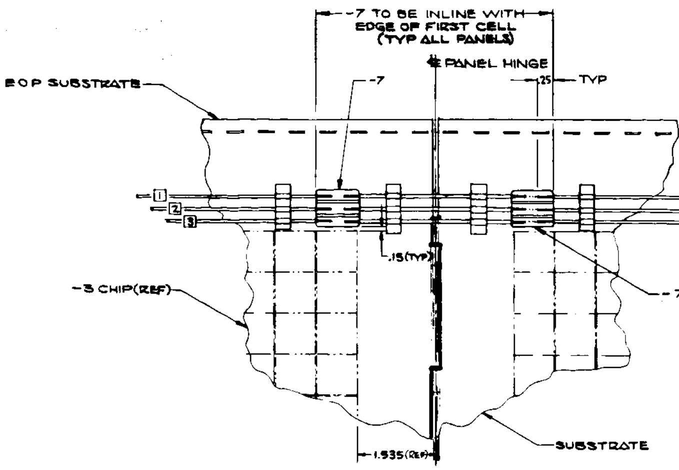


VIEW B 9
(LOCATING -5 ⌀ SHOWING MATRIX SERIES HOOKUP)
SCALE 1/1

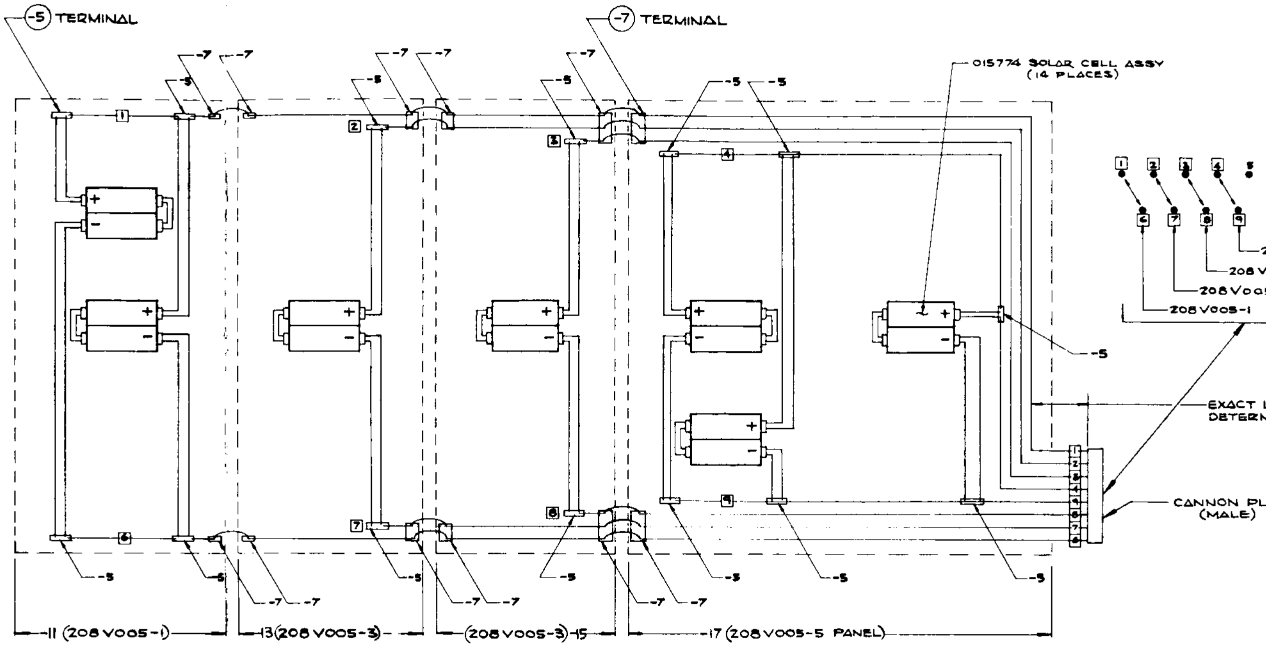


8-1

FOLDOUT FRAME

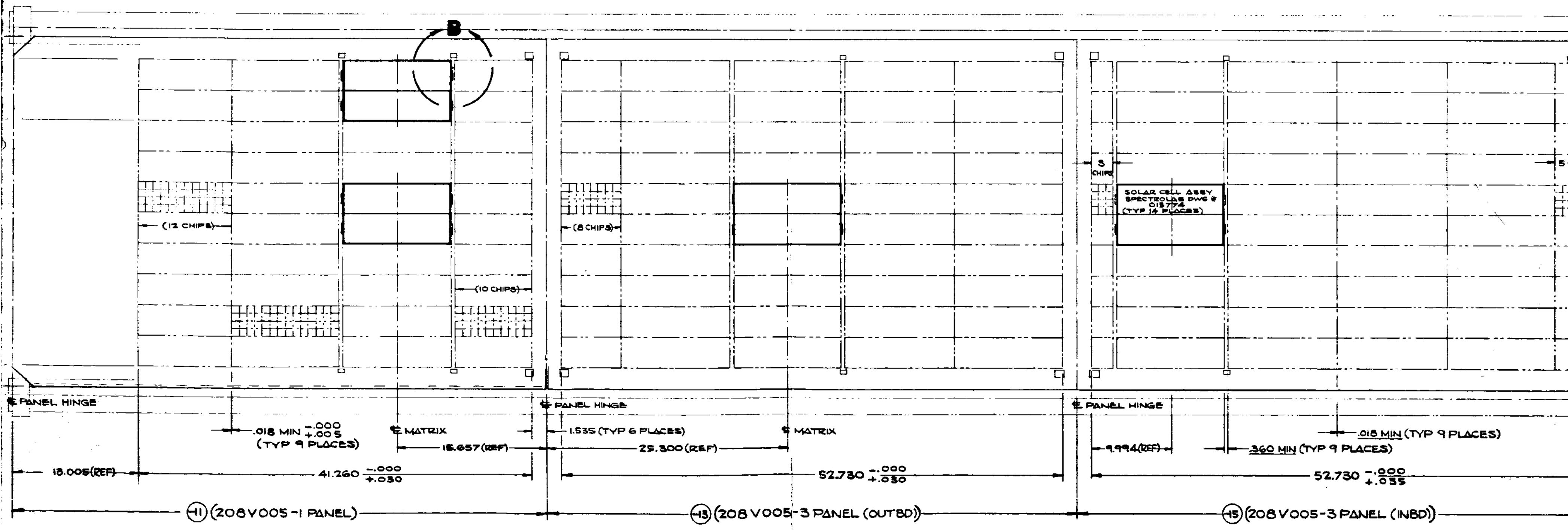


VIEW A
(LOCATING -7 ℄ SHOWING INTER PANEL JUMPER WIRES)
SCALE 1/1



WIRING DIAGRAM - SCHEMATIC

>— WRAP DIRECTION —>



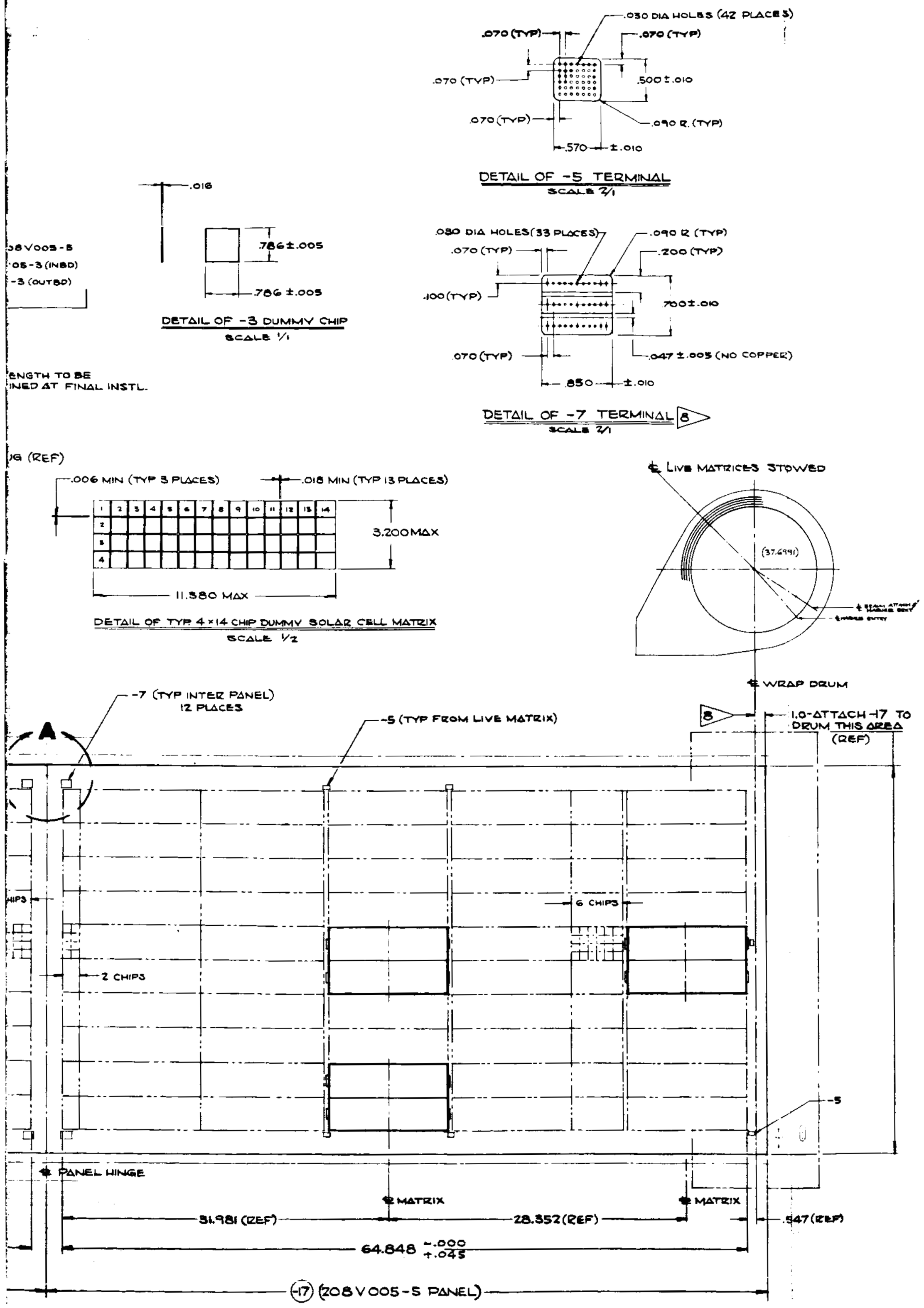
VIEW LOOKING AT SOLAR CELL SIDE OF SUBSTRATE
SCALE 1/4

DASH NO.	PANEL #	CHIPS REQD
-11	1	1776
-15	3 (INBD)	2448
-13	3 (OUTBD)	2448
-17	5	2784
	TOTAL	9456

FOLDOUT FRAME

2

FOLDOUT FRAME



11. JUMPER WIRES TO BE INSTALLED ON 208V001 (NEXT ASSY)

10. TO DETERMINE THE AMOUNT OF STRESS RELIEF REQUIRED FOR A WIRE RUN IN THE WRAP DIRECTION, MEASURE THE DISTANCE BETWEEN SOLDERED CONNECTIONS AND MULTIPLY THIS DISTANCE BY .004. ADD RESULTING FIGURE TO MEASURED DISTANCE (WITH ALLOWANCE FOR SOLDERING). DISTRIBUTE STRESS RELIEF EQUALLY THRU OUT WIRE RUN.

9. SOLDERING PER RMS-111

8. BOND WITH EPON 956 - SEE 208-3-002-A

7. MATERIAL FOR -5 AND -7 TERMINALS

5. MUST CONFORM WITH RYAN PROCESS SPEC # 208-S-003 "MODEL 208 SOLAR ARRAY-INSTL OF ACTIVE & DUMMY SOLAR CELL SUBMODULES"

4. PAINT (ON ONE SIDE ONLY) WITH LAMINAR X-500

3. SHEET STOCK TOLERANCE: $^{+.000}_{-\text{STD}}$ SHT. TOL.

2. USE EXISTING PARTS (FROM 208V001-1)

1. CUSTOMER FURNISHED

NOTES

Figure 3. Solar Cell and Wiring Layout for Test of Deployable Solar Panel

3 FOLDOUT FRAME

FOLDOUT FRAME

The cell submodules are 4 x 14 groups of 8 mil 2 cm x 2 cm silicon solar cells with 3 mil cover slides. The submodules have been wired to provide 28 cells in series in each panel group. Each of the four substrate modules is connected to the receptacle located on the support structure, permitting separate measurement of the performance of each panel module.

Aluminum alloy dummy chips, 0.016 inch thick, were used to simulate the mass of solar cells and wiring elsewhere on the panel surface. The total weight of all electrical circuitry, cells, dummy chips, and adhesive is 15 pounds. The solar cells are bonded to the substrate using RTV 40 adhesive. Process specification 208S003 was prepared to control the method of application of solar cells, dummy chips, and wiring installation. (See Appendix).

A deployment support fixture was designed for support of the panel during horizontal deployment, drawing SK9112 (See Appendix). This fixture provides roller support under the beams and also under the deployable substrate. The fixture has been provided with optional positions so that the array may be supported and deployed with the cells up or down, with or without substrate support. A counterbalance arrangement provides a means for simulating the 0.2g cruise maneuver load. This fixture is designed to be used to support the array during deployment and retraction in thermal-vacuum tests. The substrate support rollers are covered with silicone sponge rubber and are separated sufficiently to make negligible any blocking of the panel rear surface.

Two vibration fixtures have been designed to support the panel during launch environment tests. The fixtures, of welded magnesium plate, are shown in drawings TR-1148-1 and TR-1148-10 (See Appendix).

An arrangement of electrical test equipment was designed and assembled to facilitate checking electrical characteristics in accordance with the test plan. The application of this equipment in the test program is duscussed in Section 2.4 of this report.

2.3 RESULTS OF PRINCIPAL TESTS

The principal test conducted in this period is the cruise maneuver acceleration test.

2.3.1 Simulation of Cruise Maneuver Acceleration

This test was conducted to simulate a normal-to-panel loading equal to a 0.2g steady state cruise maneuver and a 0.05g steady state cruise maneuver lateral (in plane) loading with the panel in the deployed position. Load distribution and bending moments were of concern with the 0.2g loading whereas with the 0.05g loading, a concentrated tip load was applied to simulate only maximum moment. The test was conducted in a sea-level environment with the 1g environment corrected to 0.2g using (1) mass balances for the beams (see pages 8 through 10, Ryan Report No. 20865-1) and (2) lighter mass on the substrate than 0.3 pound/square foot accomplished using masking tape. After correcting the loading to compensate for a 6 percent reduction in beam modulus of elasticity due to increased temperature of the beams when deployed in space, the added panel weight required was 1.36 pounds (see pages 6 and 7, Ryan Report No. 20865-1); the actual weight added, using three-inch wide masking tape, was 1.23 pounds. The fixture to which the panel mounts and is supported as it deploys is shown in the Appendix, Ryan Drawing No. SK-9112.

2.3.2 Test Procedure

The sequence of testing was as follows:

a. Deploy panel, with cell side up, out over support rollers in a 1g ambient environment and check lateral position of beam tips. Then counterbalance 79% of beam weight, remove support rollers, manually lower beams until beams completely support load, and measure beam tips and substrate deflections after two minutes. Manually raise beams to horizontal position, add support rollers, and retract substrate. Deploy and check beam tip lateral position again. Record time to retract and deploy panel. This constitutes one test cycle.

   There was a deviation at this point in the test from the original test plan (see pages 5 through 12, Ryan Report No. 20865-1). For convenience only, the lateral load test was next conducted.

b. Add beam mass balance, remove support rollers, and support panel tip with tip roller. Measure panel tip lateral position and apply a 0.6 pound (includes 6% increase to compensate for room temperature testing) lateral load, by spring scale, at beam tip to give an equivalent bending moment at beam guides due to 0.05g acting in the plane of the panel. Record deflection, release load, and check lateral position of beam tips to determine any permanent set. Then apply load in opposite direction. Record deflection, release load, and check lateral position of beam tips to determine any permanent set. This consitituies the 0.05g load simulation test.

   At this point, add support rollers, remove mass balances, retract panel, redeploy, and check lateral position of panel tips. Record retraction and deployment time. Retract panel, remove from fixture and remount for normal-to-plane 0.2g simulation load with cell side down.

c. Test similar to test (a) above, but with cell side down.

2.3.3 Test Results

The test results are given in the order of procedure presentation above and compared with analytical results given in Report Report No. 20869-2.

a. Cell Side Up, 0.2g Simulation

- Panel deflection measured at beam tip, 24 7/16 inches (by analysis, 17 inches, see page 95, Ryan Report No. 20869-2). Deflection was greater than calculated largely due to looseness of beam at guide.

- Substrate deflection (see Figure 4), 3 5/8 inches.

- Lateral beam deflection (two beams), 13/16 inch (by analysis, 10 inches, see page 76, Selected Design, Ryan Report No. 20869-2)

- Retract time, 3 minutes, 17 seconds

- Deploy time, 3 minutes, 14 seconds

  NOTE: The lateral beam deflection was less than expected by analysis because analysis assumed the substrate to be cut to the same width as the beam spacing, in which case larger lateral catenary loads would be transferred to the beams. The effect of this is only about a 20% reduction in lateral beam load and about an equal reduction in panel normal to plane deflection. The balance (larger percent) of the difference between test and analysis is probably due to the amount of fixity provided at the beam ends; fixity error of 72% increase is necessary in addition to the reduction in lateral load due to the excessive substrate width, to justify the reduction. This large an error in fixity is questionable and must be verified by a load-deflection test before we can be certain that this is where the difference is.

No permanent set or elastic buckling of the beams occured as a result of this limit load test. The beam tip lateral position was the same after redeployment.

b. <u>0.05g Simulation</u>

- Panel deflection measured at beam tip, 1/8 inch either direction (by analysis, 1.5 inches, see page 40, Ryan Report No. 20869-2).

- Retract time, 3 minutes, 17 seconds

- Deploy time, 3 minutes, 14 seconds

NOTE: The lateral deflection was less than expected by analysis because analysis assumed the beam substrate attach clips do not transfer shear immediately.

No permanent set or elastic buckles occurred as a result of this limit load test. The beam tip lateral position was the same after loads application in each direction.

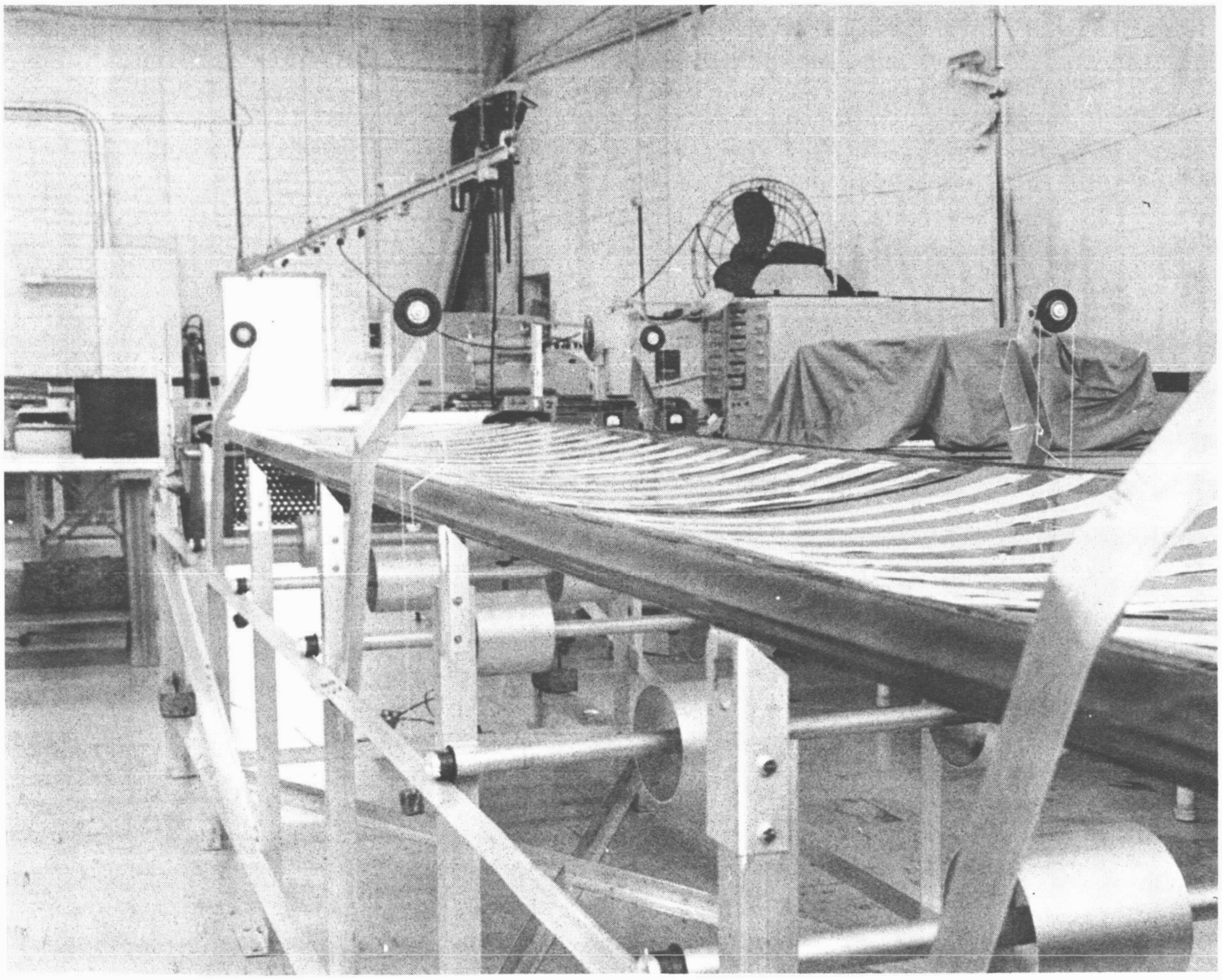


Figure 4. Substrate Deflection Showing
Tape Added to Simulate Mass

c. Cell Side Down, 0.2g Simulation

The panel supported approximately 65% of the required bending moment, equivalent to about 0.13g, when elastic buckling of the titanium beams occurred within the guide sleeves with the beam tips deflected 20 inches. It was determined that the reason for premature elastic buckling of the beam was due to insufficient support by the guide sleeves (in the substrate cutaway area), allowing the beam to flatten somewhat (see Figure 5) as it is distorted at the guide, reducing its structural stiffness. Calculations indicatedthat a section of beam, acting as a doubler, would be required along each beam cap in the guide unsupported area. A section of beam, approximately 12 inches long x 1.7 inches wide was then bonded to each beam in those areas (see Figure 6) using 1200 primer and Dow Corning RTV 3145 adhesive. After cure, the test was re-run with success.

- Panel deflection measured at tip, 20 inches (see Figure 7)

- Retract time, 3 minutes, 29 seconds

- Deploy time, 3 minutes, 13 seconds

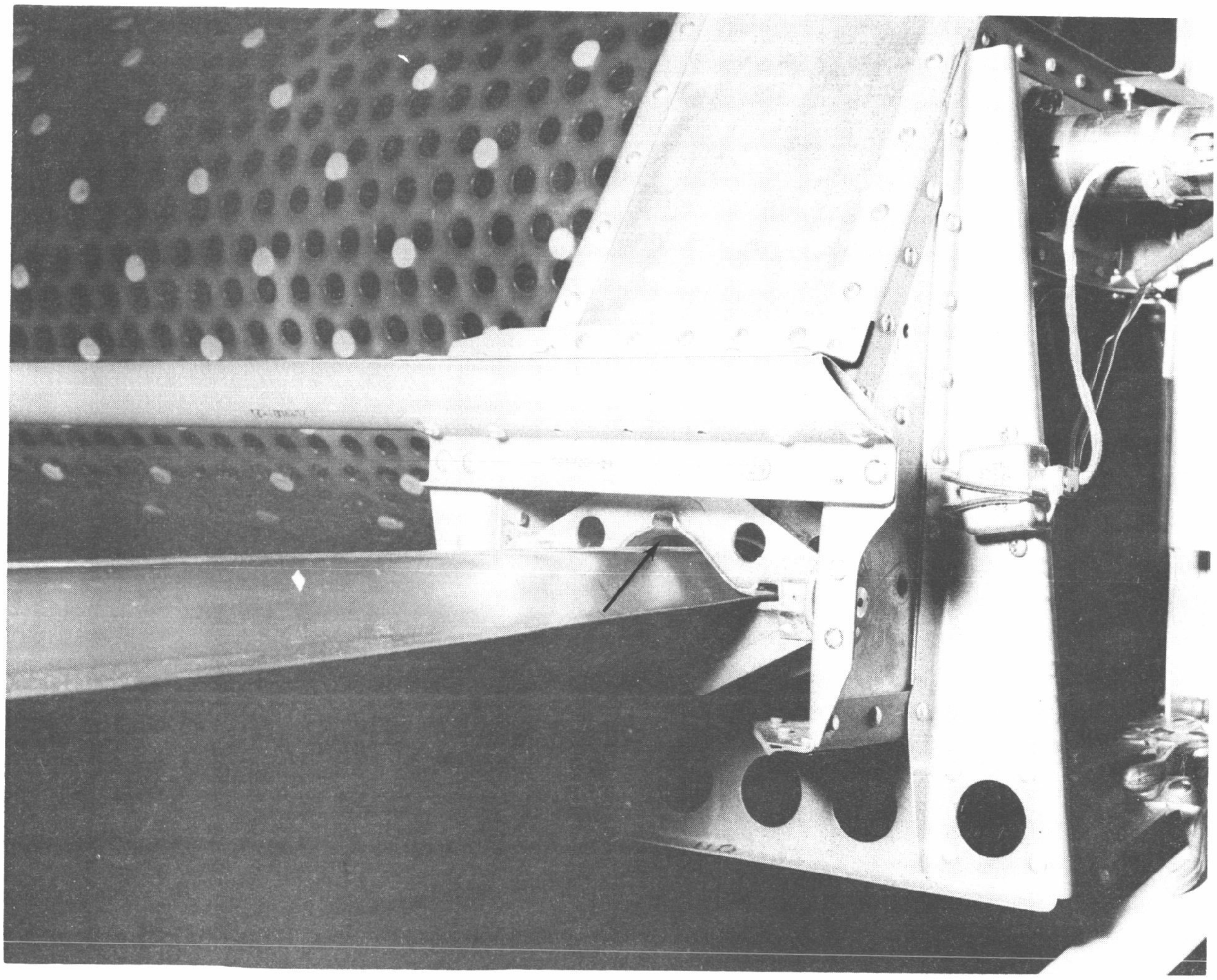


Figure 5. Beam Pull-Away at Guide-Sleeve When Loaded (Cell Side Down)

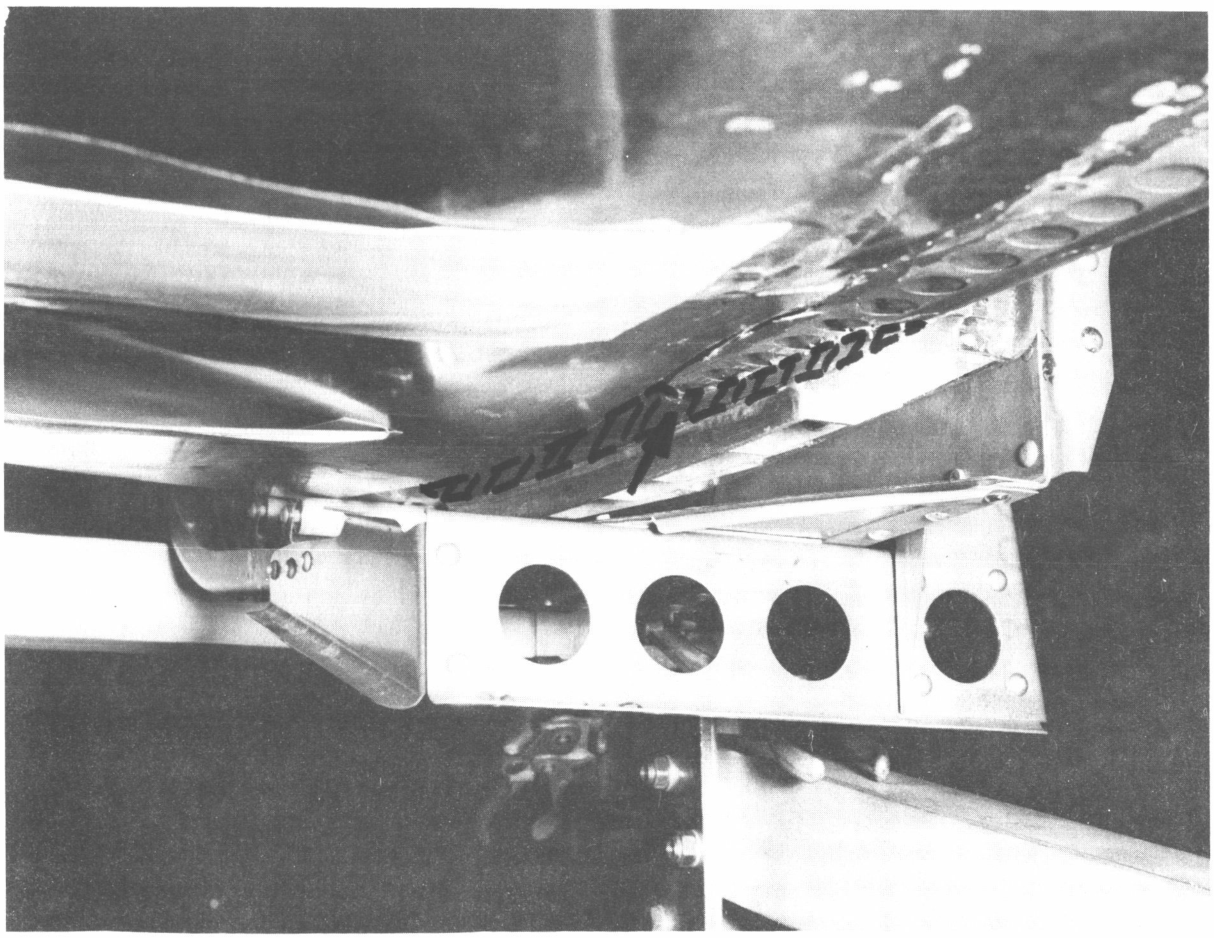


Figure 6. Beam Cap Doubler Added At Guide For Loading (Cell Side Down)

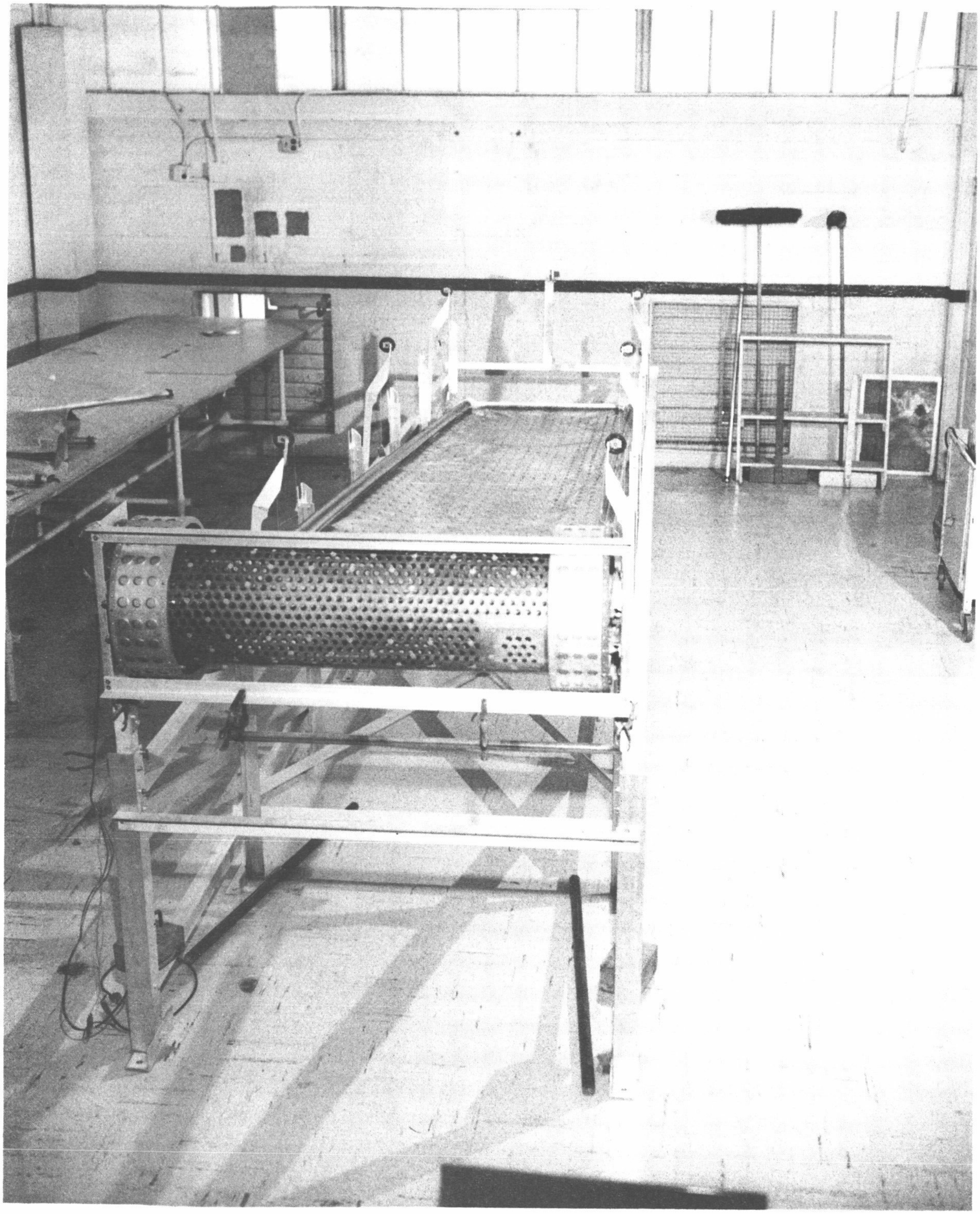


Figure 7. Deflected Panel Under 0.2g Loading (Cell Side Down)

No permanent set or elastic buckling of the beams occurred as a result of this limit load test after the beam doublers were added.

2.3.4 Assembly of Solar Cell Array

Sixteen 4 x 14 submodules were provided by JPL for installation on the substrate. The electrical performance of each matrix was measured and I-V curves plotted. These curves are available for reference at this contractor's facility. The tests were conducted outdoors in direct sunlight. Solar illumination was determined by a secondary standard cell furnished by JPL. These results were correlated with the performance data obtained by Spectrolab Division of Textron, Inc., using a solar simulator intensity of 140 mw/cm^2. Figure 8 shows the short circuit current plotted with respect to light intensity and indicates the degree of correlation with the Spectrolab data.

After completion of the 0.2g cruise maneuver test, the modular substrates were removed from the beams. Installation of solar cell submodules and dummy cells was accomplished in accordance with drawing 208V013 (Figure 3) and process specification 208S003.

Some problems were encountered during assembly of the solar cell arrays. These involved possible variation in adhesion of solar cells to the fiberglass substrate and some incidents of cracked solar cells during application and installation of the substrates on the array structure.

Variations which occurred in the preparation of the fiberglass substrate with respect to the amount of sanding and adhesive primer thickness could have an effect on low temperature adhesion of the solar cells. In order to measure these effects, an evaluation test to determine the effect of process variables was conducted. This test which is described in detail in Section 2.4, indicates that the variations which existed on the solar panels did not prevent satisfactory adhesion of the solar cells.

Of more significance were problems in handling of the solar panels during application and assembly. Handling facilities provided consisted of flat boxes lined with foam, flat support tables, and the roller support fixture previously described (see Figure 4). For installation of the solar panels to the support beams, a special plywood board was placed on top of the support rollers to provide a flat surface beneath the substrates.

When assembly was complete, cracks were noted in 25 of the 784 active cells on the array. The majority of these cells (about 20) were damaged during assembly of the substrates to the beams. The number of cracked cells was much higher than anticipated and can be attributed primarily to two causes. There was some diversion of attention from care in handling the solar panels to problems of assembly to the beams. The substrate slots and beam slots were not exactly coordinated and required special edge connectors to be attached. Also, substrate widths varied and presented some assembly difficulties. The other factor involved the roller support fixture itself. When the special board was removed, it was evident that the central support rollers under the substrates were spaced too far apart to give proper support to the panel and caused undesirable bending of the solar cell modules.

The fixture was then temporarily modified to remove the central support rollers in order to prevent further damage to the cells during deployment cycles.

Figure 9 is a photograph of the completed solar cell installation on the panel, ready for deployment cycling tests.

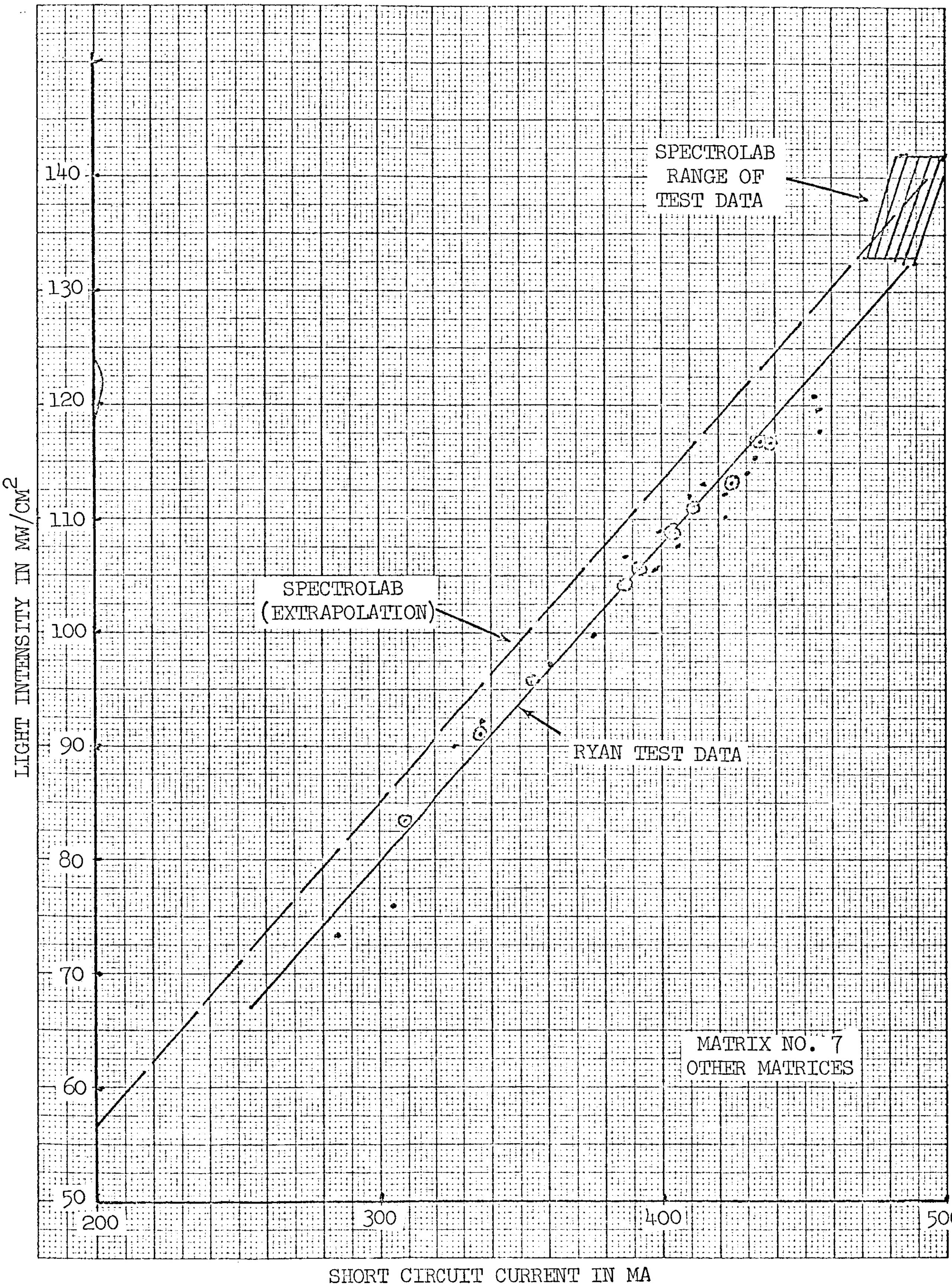


Figure 8. Comparison of Ryan and Spectrolab Test Data on Solar Cell Matrices

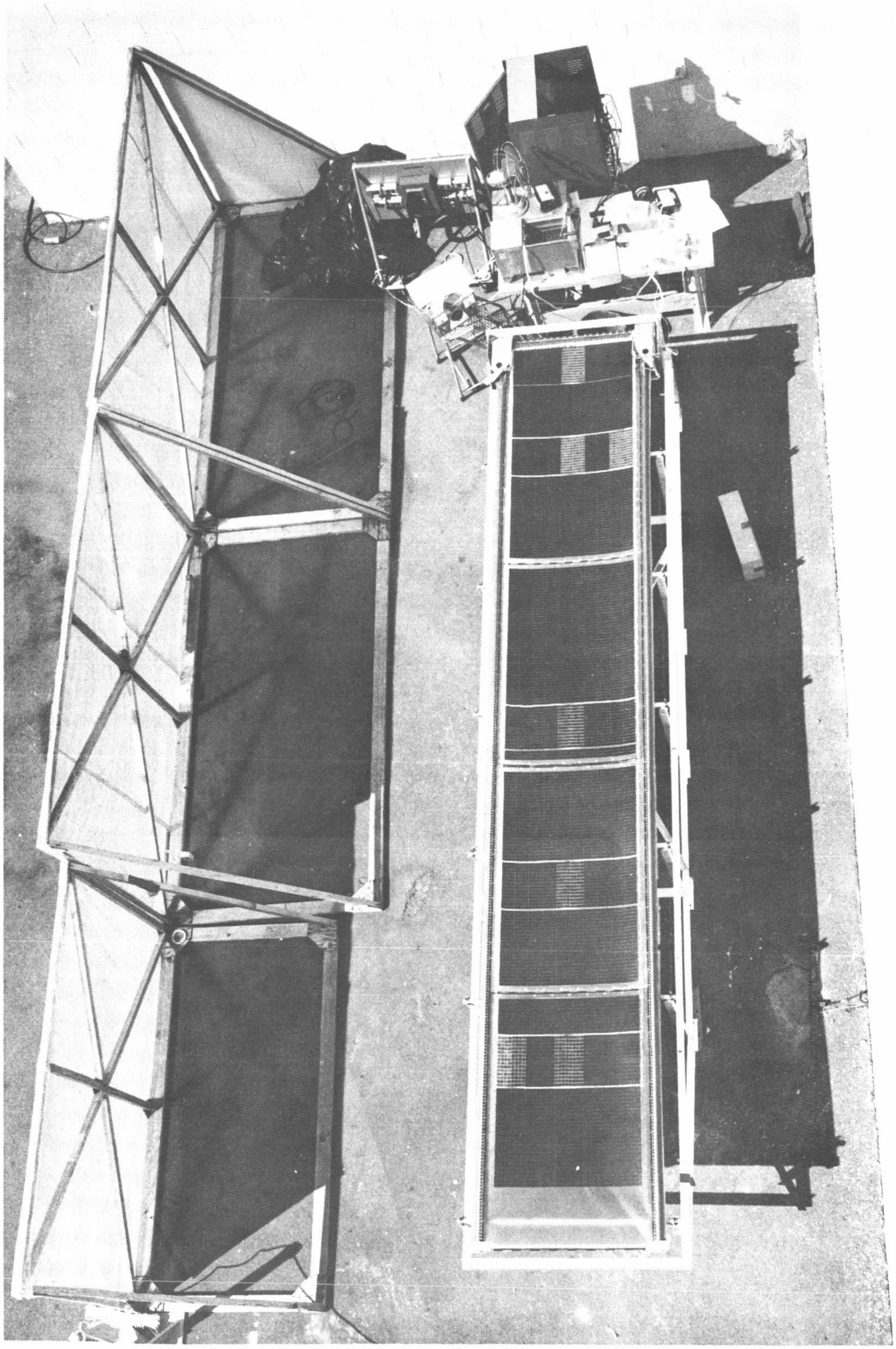


Figure 9. Solar Cell Installation On Deployable Array

2.4 ENVIRONMENTAL CONSIDERATIONS

Additional investigation of the potential effect of several specific environments on the array was conducted. One consideration was the effect of low temperature (-150°F) on the adhesion of RTV-40 bonded solar cells and cummy chips to the fiberglass substrate. This adhesion is of concern during deployment of the array in thermal-vacuum test cycles. A test was planned and conducted to measure this effect. The tests results are described in Paragraph 2.4.1 discussion which follows:

At the request of JPL, the effect of Mariner 69 launch environment on the deployable array was also considered. Critical launch environment for the hypotehtical mission specified in this contract is 4.0g rms at 20-200 cps. For the Mariner 69 launch environment, a level of 7.5g rms (30 to 250 cps) is given for evaluation. This analysis is presented in Paragraph 2.4.2.

2.4.1 Test Results

Supporting tests which were performed in this period of performance and are reported herein include:

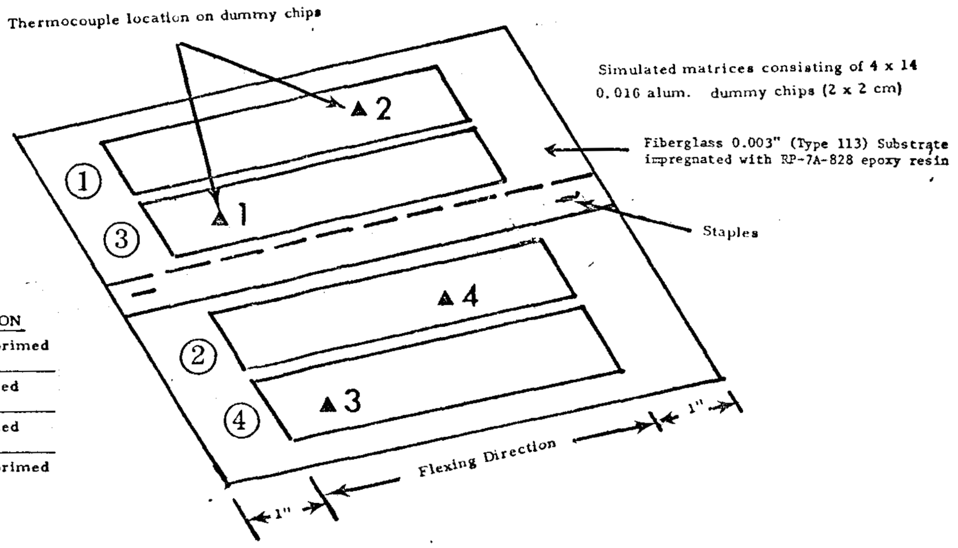
- Adhesive Bond Test-Solar Cells to Substrate
- Preliminary Check of Panel Strain in Solar Cell Area

2.4.1.1 Adhesive Bond Test of Solar Cells to Substrate

This test was conducted to obtain a high degree of confidence in the compatiblity of the adhesive bond joint (between the solar cells and fiberglass substrate) with the environment to which it will be subjected in this program. The test specimens will be subject to only the most critical of these environments, namely deployment from a wrapped position in a low temperature vacuum environment. Photographs of the specimen before and after testing and of test setup will be taken.

Test Procedure

a. The approach was to first determine the best method of preparing the surfaces to be bonded, using aluminum dummy chips bonded to the fiberglass substrate in the configuration shown in Figure 10.



SPECIMEN	PREPARATION
1	Moderately primed with sanding
2	Heavily primed substrate*
3	Heavily primed with sanding
4	Moderately primed substrate*

* G. E. S-4004

Figure 10. Surface Preparation Investigation Specimens Using Dummy Chips

After bond is completed an ambient pre-test bond condition will be noted by (1) hand flexing the specimens in an approximate two inch radius arc with dummy chips on outside of arc, (any loose bonded edges will be noted), (2) performing a cleavage test on random dummy chips of each matrix using a load test indicator such as a spring scale with a right-angled loading tip. A load of one pound will be applied and any failures noted. The specimens will then be mounted on the test fixture as shown in Figure 11. The four ounce preload is intended to approximate possible load in the substrate as it wraps on the drum in the actual condition.

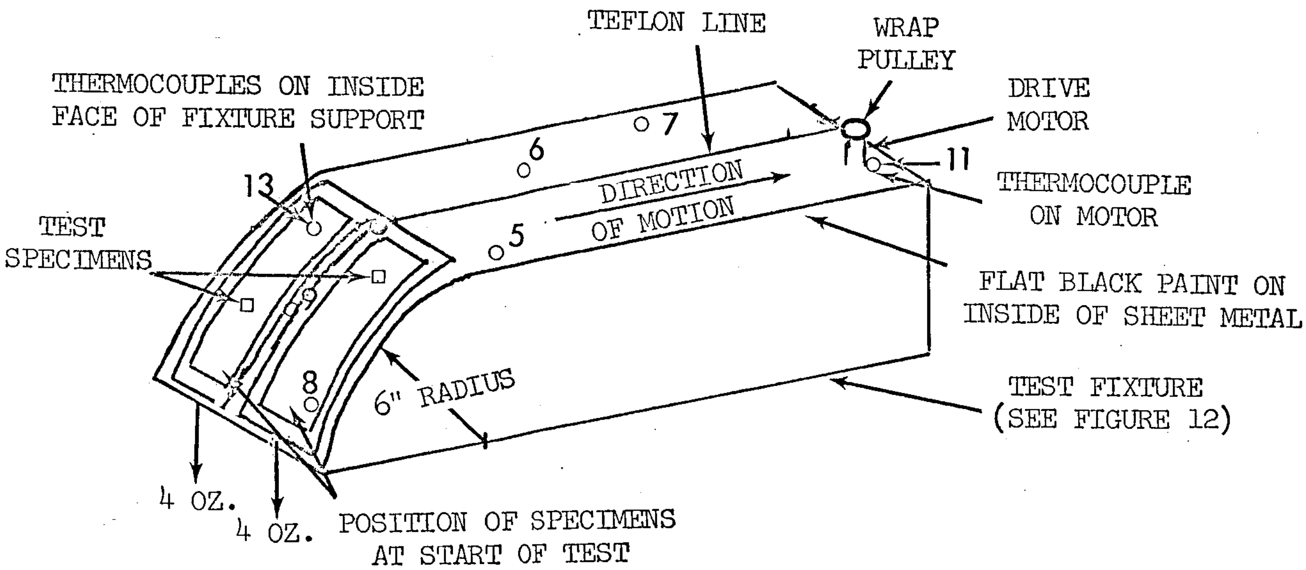


Figure 11. Specimens Mounted on Fixture

The test fixture (Figure 12) will be mounted in a vacuum chamber. The chamber atmosphere will be reduced to 10^{-4} torr or less and the cold wall shroud flooded with LN_2 at a rate such that the specimen temperature is not reduced faster than 50°F/min. Four #36 gage copper constantan thermocouples, one mounted on each specimen, will be used to monitor temperatures. When the recorded specimen temperature is stable at about -150°F (stabilized temperature based on about 5°F/hour change), the drive motor will be activated which will pull the specimens from the curved position into a flat position at a rate of about 4.4 ft/min. The test specimens will then be removed from the chamber and adhesive bond condition of each dummy chip checked at room temperature by flexing in a six inch radius.

Any loose bond edges will be noted for the flex radius check and percent of occurrences noted with respect to total number of dummy chips (with acceptable bonds prior to tests) on that respective matrix. The bond preparation most suitable for further investigation will be selected from the matrix with the least percent edge bond failure when flexed in a four and two inch radius arc. Edge bond failure for a six inch radius arc is not acceptable. A cleavage test of the same chips checked prior to test will be performed and compared with those results.

b. Secondly, two wired solar cell matrices will be bonded to a fiberglass substrate using the selected bond preparation determined from tests with the dummy chips. The specimen will be tested in the same manner as the dummy chip specimens. Data will be forwarded to engineering for review and determination if bond if satisfactory.

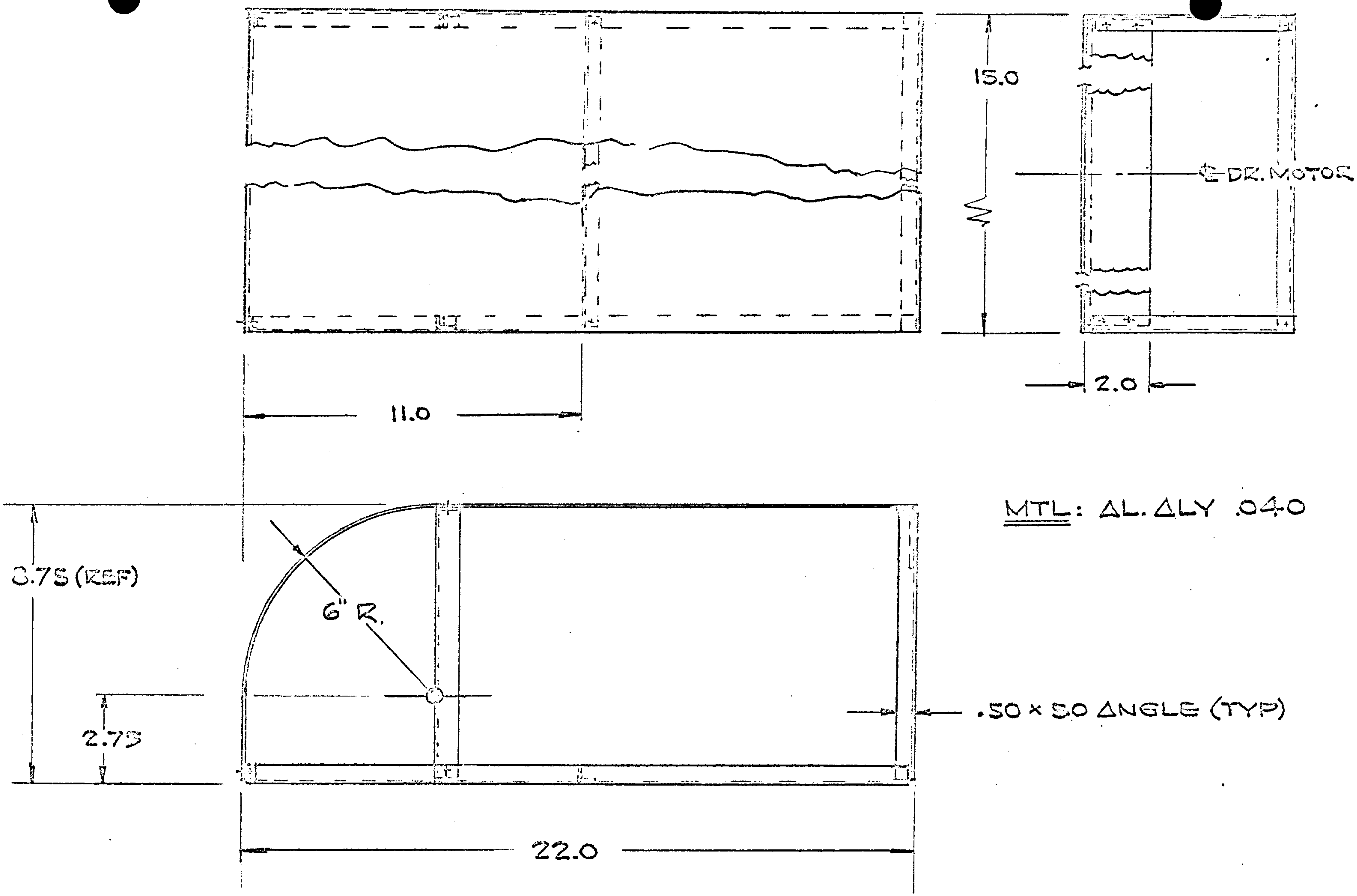


Figure 12. Test Fixture

Test Set-Up

The cleavage test setup is shown in Figure 13. Figures 14 and 15 show the specimen on the fixture for use in the vacuum chamber in (a) the start of test and (b) end of test positions, respectively. Figure 16 shows the specimen in position in the vacuum chamber and the lamp to give light for monitoring visually with the vacuum chamber door closed.

Figure 13. Cleavage Test Set-Up

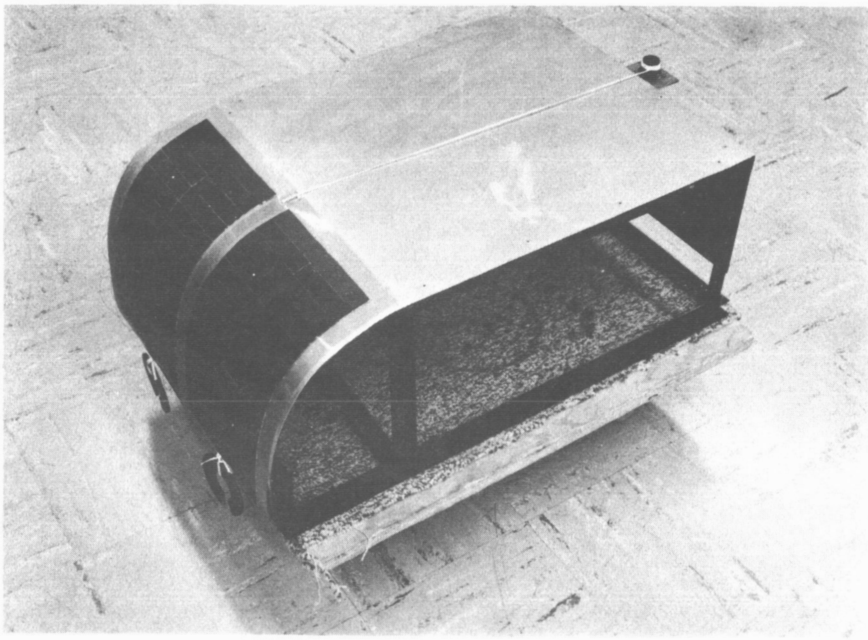


Figure 14. Specimen on Fixture in Start of Test Position

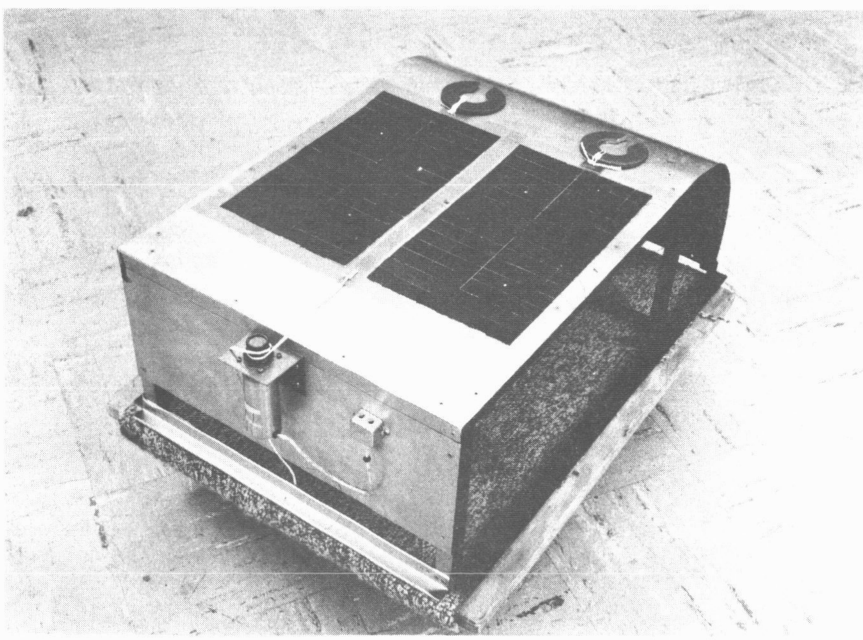


Figure 15. Specimen on Fixture in End of Test Position

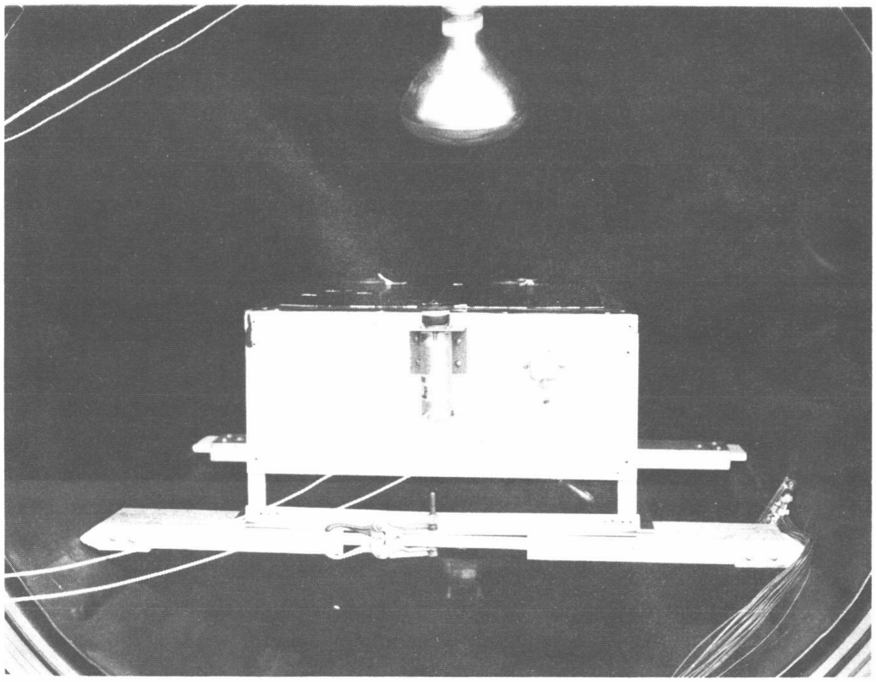
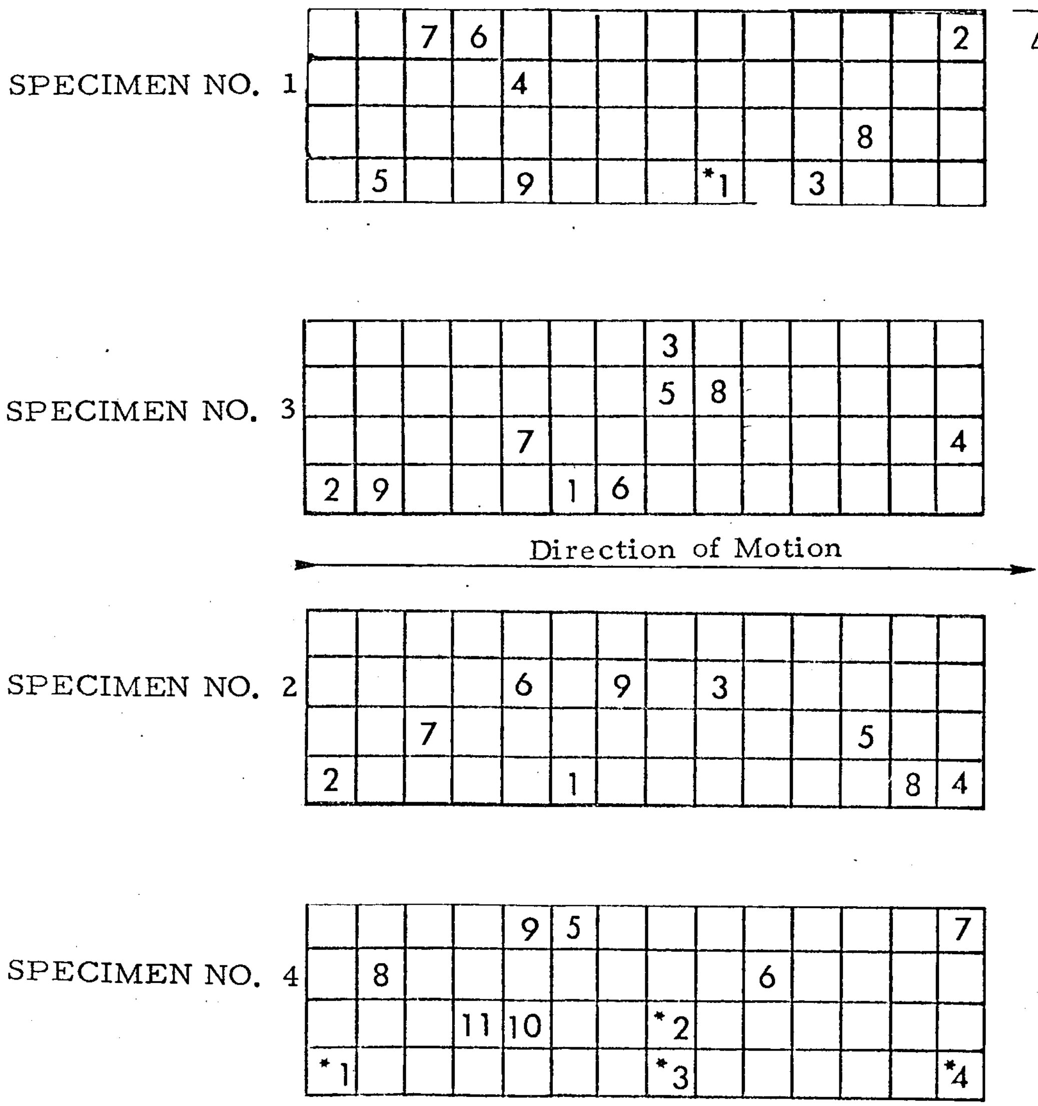


Figure 16. Specimen on Fixture in Vacuum Chamber

Bonded Dummy Chip Test Data

Cleavage Test Data - Data is presented in Table 1. Figure 17 shows location of specimen cells monitored.

SPEC NO.	PREPARATION
1	Moderately primed with sanding
2	Heavily primed with G.E. S-4004
3	Heavily primed with sanding
4	Moderately primed



* Questionable bonds prior to vacuum test (Loose chip at edges)

Figure 17. Location of Specimen Cells Monitored

TABLE 1

RESULTS OF BONDED DUMMARY CHIP CLEAVAGE TEST

One Pound Load Test	High Load Test	
Prior to Vacuum Test	Prior to Vacuum Test	After Vacuum Test
Specimen No. 1		
1 - ok		
2 - ok		
3 - ok		
4 - ok		
5 - ok		
6 - ok		
7	10 lbs. -ok	10 lbs. -ok
8	5 lbs. -ok	5 lbs. -ok
9	5 lbs. -ok	5 lbs. -ok
Specimen No. 2		
1 - ok		
2 - ok		
3 - ok		
4 - ok		
5 - ok		
6 - ok		
7	10 lbs. -ok	10 lbs. -ok
8	5 lbs. -ok	5 lbs. -ok
9	5 lbs. -ok	5 lbs. -ok
Specimen No. 3		
1 - ok		
2 - ok		
3 - ok		
4 - ok		
5 - ok		
6 - ok		
7	10 lbs. -ok	10 lbs. -ok
8	5 lbs. -ok	5 lbs. -ok
9	5 lbs. -ok	5 lbs. -ok
Specimen No. 4		
1 - lifted 50% of area		2.7 lbs. - complete failure

TABLE 1

(Continued)

One Pound Load Test	High Load Test	
Prior to Vacuum Test	Prior to Vacuum Test	After Vacuum Test
Specimen No. 4 (Cont) 2 - lifted 50% of area		1 lb. - held
3 - complete failure		
4 - lifted 50% of area		1 lb. - held
5 - complete failure		
6 - ok		2.5 lbs. - failed
7 - started to lift		1 lb. - held load
8 - ok		1 lb. - ok
9 - started to lift		0.63 lb. - failed
10	Failed at 2 lbs. - primer to substrate	
11		2.5 lbs. - complete failure

Temperature Data

Temperatures were recorded at the specimen fixture and drive motor; (1) before vacuum test began (cold soak took approximately 3 hour to reach stabilization) and (2) during movement of specimen from 6 inch radius arc to flat position (simulating panel deployment). Results are presented in Table 2. Deployment time took 4 seconds longer at test temperature (-150°F) as compared to 15 seconds at room temperature.

TABLE 2

TEMPERATURE AT START OF TEST AND DURING TEST

	Thermocouple No.	Temperature, °F Cold Soak (3 Hrs) (Start Test)	Temperature, °F (During Deployment)
On Specimen	1	(-148)	(-144)
	2	(-152)	(-149)
	3	(-151)	(-148)
	4	(-148)	(153)
On Fixture	5	(-115)	(-115)
	6	(-65)	(-65)
	7	(-95)	(-95)
	8	(-117)	(-118)
	9	(-120)	(-120)
On Motor	11	(-74)	(-74)
On Shroud	12	(-166)	(-166)
On Fixture	13	(-123)	(-123)

Vacuum - $2.3X10^{-6}$ Torr

Conclusions

Only specimen No. 4, which had no roughened substrate surface prior to bonding and used a moderately primed substrate, did not pass the cleavage tests, either before or after deployment simulation in cold vacuum. Since no conclusion can be drawn from this test as to the better method of bond preparation between specimens 1, 2, o4 3, the two which intuitively would not be as good, (specimen 1 and 2) will be further investigated. Actual solar cell matrices will be used.

Bonded Solar Cell Test

Due to the fragility of solar cells subject to cleavage load for evaluation of the adhesive bond, a cleavage test similar to that used on the dummy chips was not performed. The solar cell bond was examined prior to test for structural integrity by noting any raised or loose solar cell edges viewed under a light with the specimen draped over a 6 inch radius of curvature plate. After the flex test in the vacuum chamber, the cells at the bond were again examined for any change in the degree of loose or raised edges.

No change in bond structural integrity was noted as a result of the flex test in vacuum after a two hour specimen soak at -150°F. For the intended usage, either bond preparation No. 1 or No. 2 may be considered satisfactory for attaching solar cells to .003 fiberglass substrate (Type 113 glass cloth impregnated with Ryan's RP7A-828 epoxy resin).

2.4.1.2 Preliminary Check of Panel Strain in Solar Cell Areas

This test is conducted to determine what possible stress can occur in the solar cell areas (cover glass considered more critical) when subjected to loading conditions simulating those which could be induced during deployment cycling. From this information, we will determine the necessity for strain gage monitoring of the panel during deployment cycle testing.

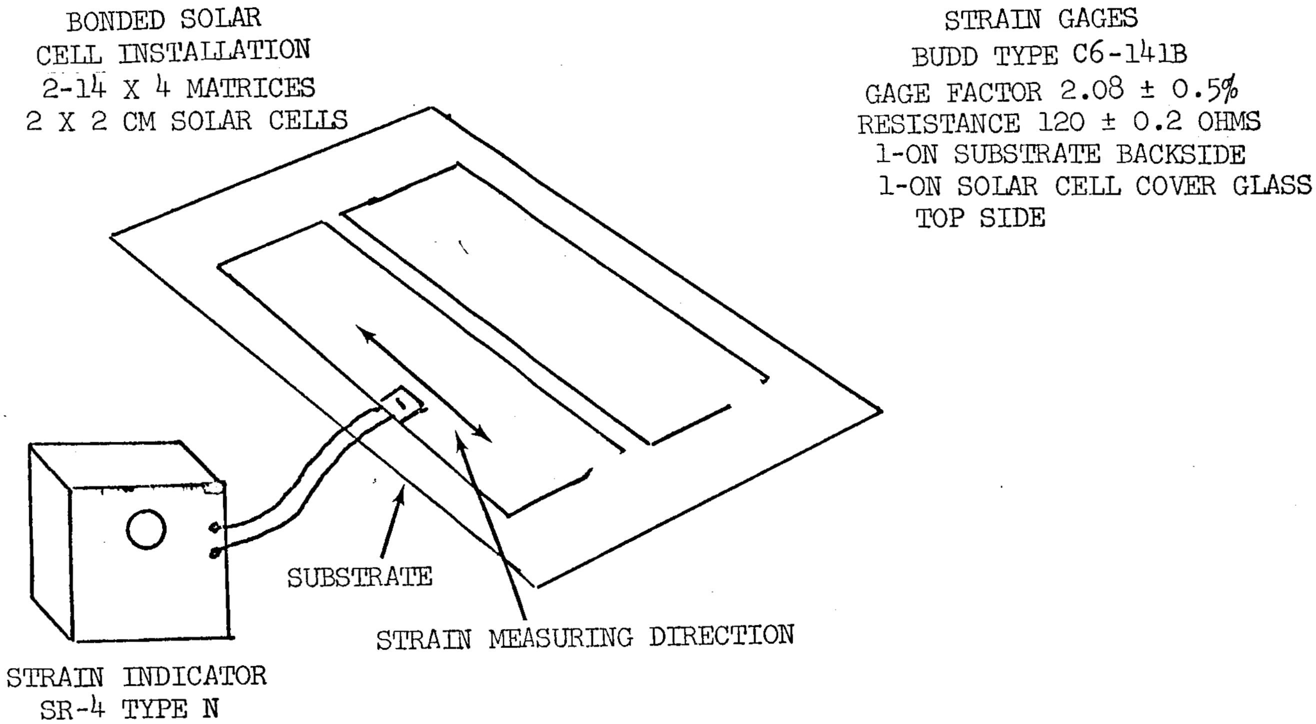


Figure 18. Test Setup for Strain Check Test

Results and Conclusions

The test results (see Table 3) show that a maximum stress in the solar cell cover-glass will occur under a combined condition of wrapping around the 6-inch radius drum and subjection to local buckling. We know that this combination of conditions can actually occur in the panel as it wraps on the drum. Since (1) we know from this test the approximate stress under this condition (1600 + 1800 = 2780 psi) and can use this to approximate solar cell stress in the visually monitored panel as it wraps on the drum, and (2) this stress is well below the fracture stress of glass and therefore damage should not occur as a result of deployment cycling of the panel, it is therefore decided not to install strain gages on the panel.

TABLE 3

RESULTS OF PRELIMINARY CHECK OF PANEL STRAIN IN SOLAR CELL AREAS

Type Load	Strain: Substrate	Strain: Cover Glass
A. 6 in. radius of curvature	195μ in/in (585 psi)	160μ in/in (1600 psi)
B. Edge compression sufficient to buckle 1/2" normal to plane	105μ in/in (315 psi)	145μ in/in (1450 psi)
0.1250	(105psi) 35μ in/in	(1000psi) 100μ in/in
0.250	(162psi) 54μ in/in	(1020psi) 102μ in/in
0.375	(234psi) 78μ in/in	(1180psi) 118μ in/in
C. Edge Tension (Approximately 4 lbs.)	170μ in/in (510 psi)	20μ in/in 200 psi
D. In-plane shear sufficient to buckle 1/2" normal to plane	75μ in/in (225 psi)	10μ in/in (100 psi)

2.4.1.3 <u>Effect of Mariner "69" Loading Environment on 50 ft^2 Deployable Solar Array</u>

The main concern will be the sinusoidal excitation increase from 4g rms (20-200 cps), for which the stowed array was designed, to 7.5g rms (30-250 cps). The areas of concern are wrap drum strength compatibility, substrate deflection to prevent wrapped layers of solar cells contacting each other and breaking solar cells, and spacecraft mount strength compatibility.

<u>Substrate Deflection</u>

Since the sinusoidal frequency bandwidth is increased above 200 cps to 250 cps for the Mariner "69" environment, it is doubtful that even if the substrate were wrapped with sufficient precision, unstressed in tension, such that all layers contacted the sponge separation pads, the layers would resonate outside the sinusoidal band. The sinusoidal response on the outer layer is calculated, assuming a damping ratio C/C of 0.04,

$$g_{(response)} = g_{(in)} \cdot Q = 7.5 \times 12.5 = \underline{94} \text{ g rms}$$

which, for a unit weight, w, of 2.37×10^{-3} lbs/in^2/layer (solar cells plus substrate) would result in an average radial pressure at the outer wrapped layer, based on a triangular dynamic load distribution (see Figure 22),

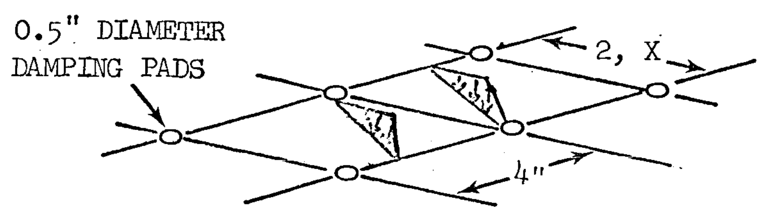


Figure 19. Position of Load Deflection

calculated as,

$$\text{average radar pressure} = 1/2\ (w \cdot g_{\text{response}}) = 1/2\ (2.37 \times 10^{-3} \times 94)$$

$$= 0.111 \text{ psi limit, } 0.134 \text{ psi ult.}$$

For the damping pad spacing, x, of 2 inch, and the damping pad diameter of 0.5 inch, damping pad pressure $= \dfrac{2 \times 4 \times .134}{\pi \times \left(\frac{0.5}{2}\right)^2} = 5.46$ psi ultimate

and for this pressure load, damper pad deflection from Ryan tests is given as approximately 0.09 inch (see Figure 20).

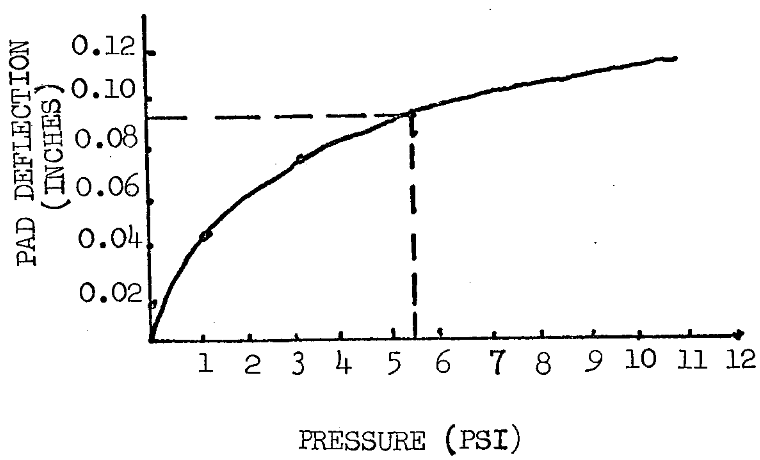


Figure 20. Damping Pad Deflection

For sinusoidal vibration at approximately 100 cps (fundamental frequency due to the manner in which the substrate wraps) the total deflection (pads and substrate) of this outer substrate layer is approximately 0.125 inch, which is the limit of the substrate to prevent contacting another substrate layer and damaging solar cells. If any two of the wrapped layers vibrate together at a lower mode, the greater pressure on the damping pads will cause adjacent substrate layers to contact each other. If we consider a reduction of 30 percent in solar cell weight (.3 lbs/ft^2 to .2 lbs/ft^2) and increase in damping ratio giving a reduction in dynamic transmissability, q, from 12.5 to 8.4, the maximum sinusoidal excitation permissable, to the wrap drum is 8.4 g* rms to prevent wrapped layer contact with only two layers vibrating together. If any more than two layers vibrate in unison, contact will occur.

$$* \ \delta : (\Delta g_{(in)} \cdot q)\ (W) = \text{constant}$$

$$g_{in.} = \frac{12.5}{8.4}\ (1/2 \times 3/2) \times 7.5 = \begin{matrix} 8.4g\ (\text{rms})\ \text{max.} \\ 11.9g\ (0\text{-peak})\ \text{max.} \end{matrix}$$

Unless the actual damping is considerably greater than anticipated, one possible solution is to add additional damping pads and probably at the same time increase their thickness to assure initial contact of wrapped layers with damping pads where the substrate wraps loosely. The increase in weight would be about 0.69 lbs. for the panel or 0.014 lbs/ft^2. It is anticipated that an external pretensioned wrap will dampen motion of the wrapped layers (both external wrap and internal wraps vibrating in unison) but at the same time will pre-load the solar cells and more so when the pre-tension effect is to be transmitted to the inner layers; therefore, pretensioning with an external wrap is undesirable

Spacecraft Mount Considerations

A load increase of 2.15 times that designed for is shown as possible in Ryan Report No. 20869-2, 5 May 1966, Final Design Report for Deployable Large Area Solar Array Structure, page 61. The actual increase considered here is:

$$\frac{7.5}{4} = 1.9,$$ Disregarding an increase, probably, in structural damping as load increases.

Wrap Drum Considerations

The above referenced report shows substantial margins of safety, in most areas, to allow a load increase as suggested. The areas which would need an increase in strength capacity are (1) riveted spindle attachment in drum end plates which would require a redesign as shown and (2) an increase in core density to effect greater shear capacity. The weight increase for the above would be about 1 pound (see Figure 21).

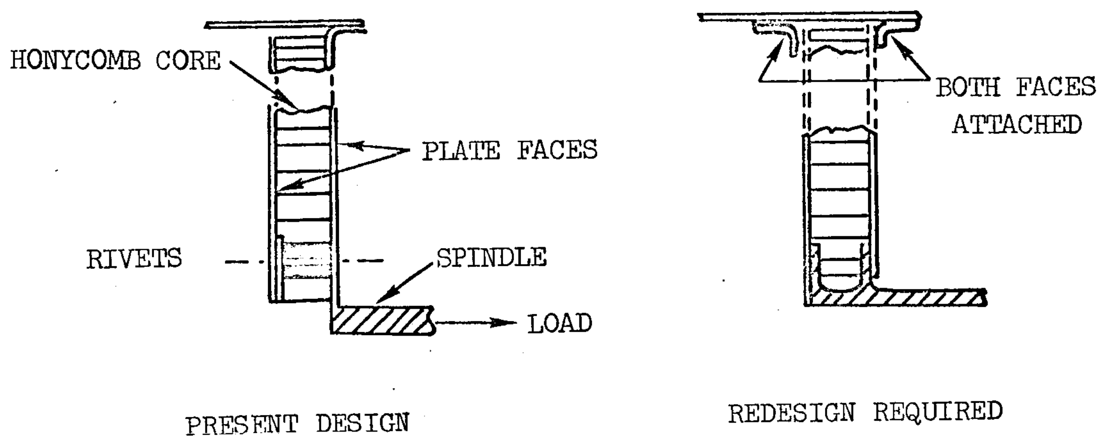


Figure 21. End Plate Design Comparison

3.0 CONCLUSIONS

During this period the solar array structure has been tested with satisfactory results in the 0.2g cruise maneuver acceleration test.

Assembly of solar cell submodules and simulated cells for mass loading was completed. The array is ready for continuation of the principle tests in accordance with the test plan (Reference 4).

Supporting tests that were conducted have indicated the approach to be taken in performance of subsequent testing and have encouraged confidence that further tests can be completed with satisfactory results.

4.0 RECOMMENDATIONS

It is recommended that the contractor continue with the testing and evaluation of the prototype solar array structure in accordance with the approved test plan and procedures contained in Report 20865-1.

5.0 NEW TECHNOLOGY

No items of a "New Technology" nature have been identified in this period of performance.

6.0 REFERENCES

1. Preliminary Developmental Report for Deployable Large Area Solar Array Structure, Report No. 20869-1, Ryan Aeronautical Company, 30 July 1965

2. Final Design Report for Deployable Large Area Solar Array Structure, Report No. 20869-2, Ryan Aeronautical Company, 5 May 1966

3. Final Report for Design and Fabrication of a Deployable Large Area Solar Cell Array Supporting Structure, Report No. 20869-3, Ryan Aeronautical Company, 28 April 1967

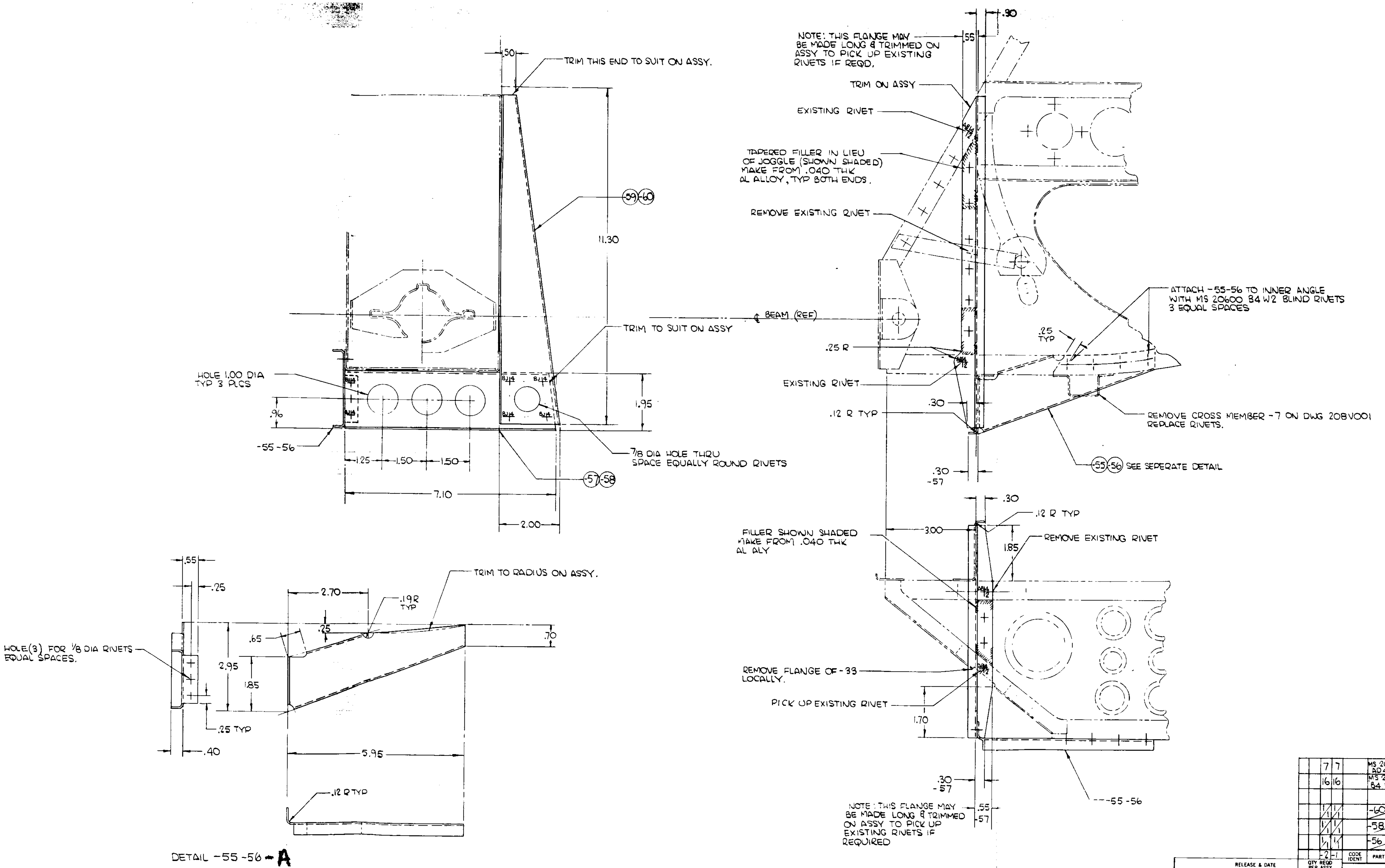
4. Test Plan and Procedures for Phase IV Non-Destrutive Testing Testing and Evaluation of the Prototype Deployable Solar Array Structure Manufactured Under Contract 951107, Report No. 20865-1, Revision A, Ryan Aeronautical Company, 6 October 1967

7.0 APPENDIX

Copies of the more significant drawings and specifications prepared during this period of the contract, are enclosed to supplement the discussion that has been presented. Included are:

Drawing No.	Title
208V006, E.O. 366013	End Cap Assembly
SK 9112, sheets 1 and 2	Test Fixture, 50 sq. ft. Rollup Details
TR-1148-1 and TR-1148-10	Fixture-Vibration, Deployable Solar Panel Test

Specification No.	Title
208S003	Process Requirements for Model 208 Solar Array -- Installation of Active and Dummy Solar Cell Submodules



WT TOTAL .374 lb

QTY REQD PER ASSY -2	QTY REQD PER ASSY -1	CODE IDENT	PART NUMBER	DESCRIPTION	STOCK SIZE	MATERIAL	SPECIFICATION	RYAN MATL CODE	ZONE	ITEM NO.
7	7		MS 20470 AD4	RIVET						
16	16		MS 20600 B4 W2	RIVET - BLIND						
1/1	1/1		-60/-59	BRACKET .032 THK	3.1 x 11.5	AL ALY 2024-T4	QQ-A-250/4			
1/1	1/1		-58/-57	BRACKET .032 THK	3.0 x 7.3	AL ALY 2024-T4	QQ-A-250/4			
1/1	1/1		-56/-55	BRACKET .032 THK	3.3 x 6.0	AL ALY 2024-T4	QQ-A-250/4			

LIST OF MATERIAL

RELEASE & DATE

FINAL ASSY	NEXT ASSY	NEXT ASSEMBLY	USED ON
QTY REQUIRED		APPLICATION	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES AND INCLUDE CHEM APPLIED OR PLATED FINISHES

TOLERANCES

LINEAR		ANGULAR
.X	±.1	EXCL OF SHEET METAL FLANGES
.XX	±.03	
.XXX	±.010	±0° 30'

PARTS TO BE FREE OF BURRS AND SHARP EDGES. MANUFACTURING REQUIREMENTS PER RYAN MFG. STANDARD NO. 130.

CONTRACT NUMBER

	SIGNATURES	DATE
DRAWN BY	L.W.W.	
GR APPD	L.W.W.	
CHECK		
STANDARDS		
STR/WT		
PROJECT		

DESIGN ACTIVITY APPROVAL

DESIGN APPROVAL

RYAN AERONAUTICAL COMPANY
SAN DIEGO, CALIFORNIA 92112

EO TO DWG 208V006
(SHEET 2)

SIZE	CODE IDENT NO.	NUMBER	REV SYM
	78022	EO 366013	

SCALE 1/1 WEIGHT SHEET 2 OF 2

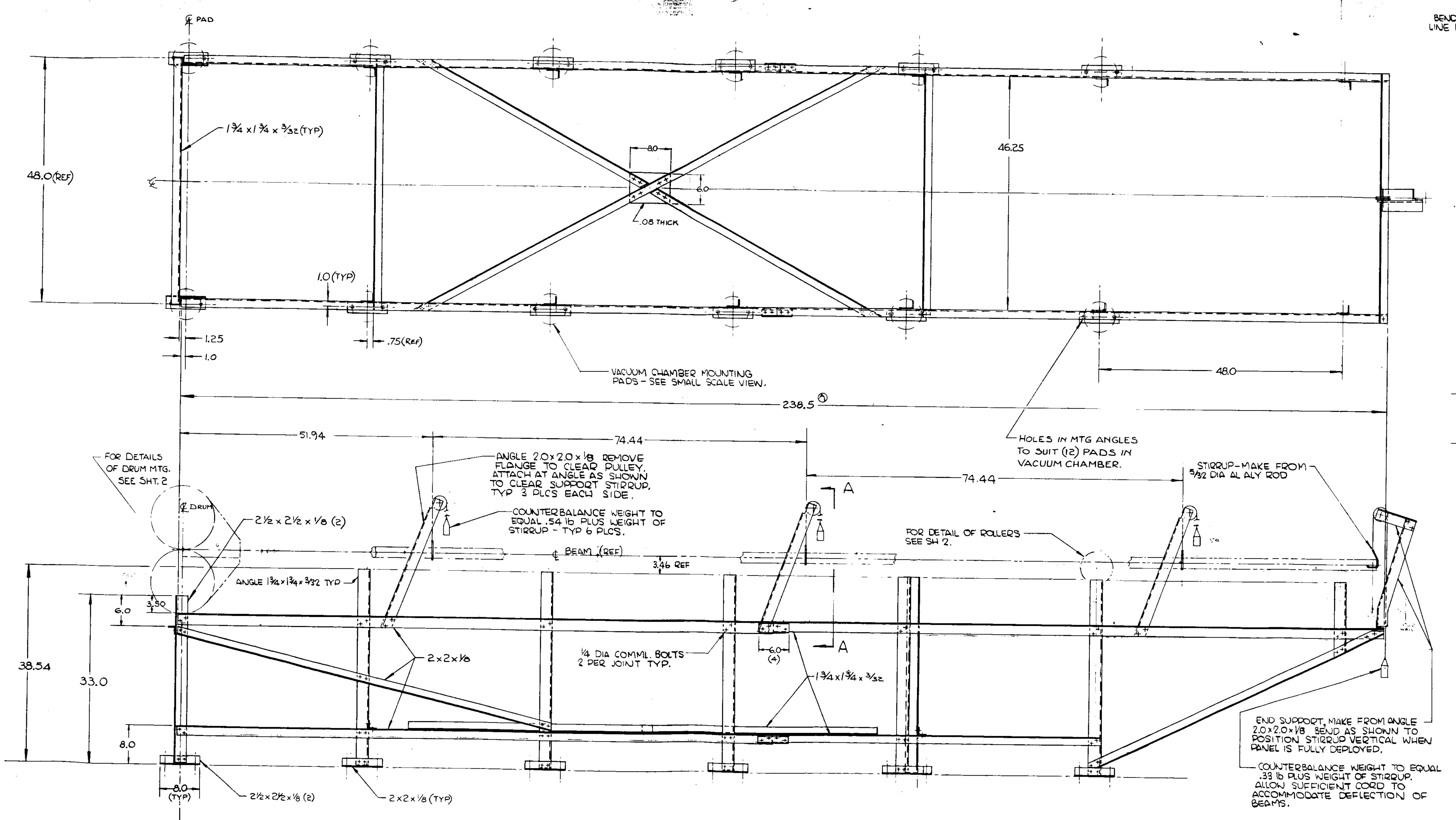
FOLDOUT FRAME

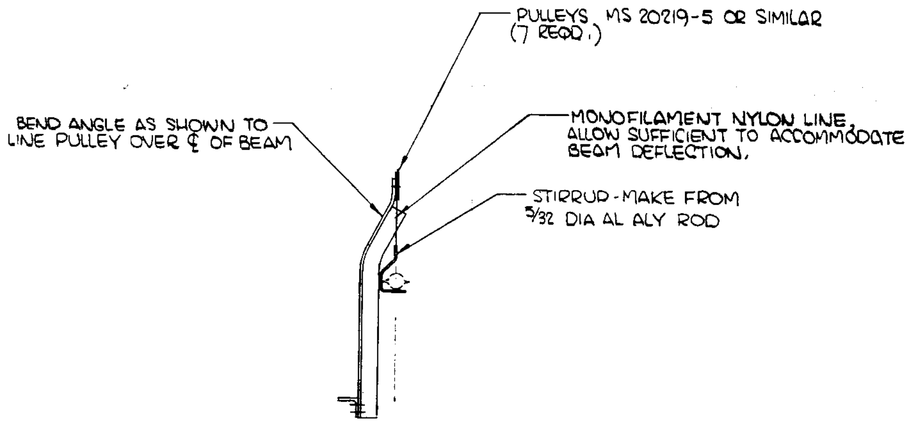
FOLDOUT FRAME

DETAIL-55-56-B

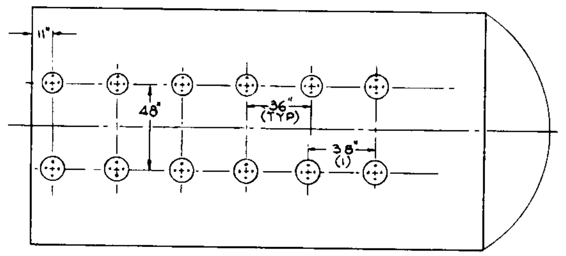
FOLDOUT FRAME

SYM	ZONE	EFF ON	REVISIONS DESCRIPTION	DATE	APPROVED
A			DIM 238.5 WAS 274.0	9-1-67	

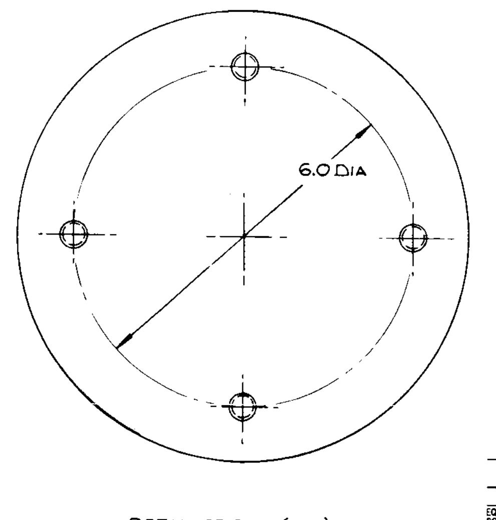




SECTION A-A
TYP 6 PLCS



VACUUM CHAMBER (REF)



DETAIL OF PAD (TYP)
FULL SIZE

MATERIAL

2½ x 2½ x 1/8 ANGLE AL-ALY 6063 QQ-A-200-9	2 2	33.0 LONG 8.0 LONG
2 x 2 x 1/8 ANGLE AL-ALY 6063 QQ-A-200-9	4 2 7	120.0 LONG 80.0 LONG 90.0 LONG 8.0 LONG
1¾ x 1¾ x 3/32 ANGLE AL-ALY 6063 QQ-A-200-9	10 2 2 1 2 4 2 4 2	40.0 LONG 120.0 LONG 66.0 LONG 110.0 LONG 55.0 LONG 50.0 LONG 15.0 LONG 6.0 LONG 66.0 LONG
.08 SHT AL-ALY QQ-A-250	1	8.0 x 6.0
1/4-20 BOLTS & NUTS (COM)	128	LENGTH A.R.
PULLEYS	7	MS 20219-5

ON SHT. 2

2½ x 2½ x 1/8 ANGLE AL-ALY 6063 QQ-A-200-9	2	19.0 LONG
2 x 2 x 1/8 ANGLE AL-ALY 6063 QQ-A-200-9	2	24.0 LONG
1/4-20 BOLTS & NUTS (COM)	AR	LENGTH A.R.

DETAIL of PAD (TYP) - A

NOTES:
1. ALL PARTS TO BE CLEAN & FREE FROM PAINT OR OIL.
2. APPROX WT. 95 lb
3. ℄ OF VERTICAL MEMBER ON ℄ OF PAD (TYP)

B

CODE IDENT	PART NUMBER	DESCRIPTION	STOCK SIZE	MATERIAL	SPECIFICATION	RYAN MAT'L CODE	ZONE	ITEM NO.
		LIST OF MATERIAL						

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE CHEM APPLIED OR PLATED FINISHES
TOLERANCES: LINEAR .X ±.1, .XX ±.03, .XXX ±.010; ANGULAR EXCL OF SHEET METAL FLANGES ±0° 30'
PARTS TO BE FREE OF BURRS AND SHARP EDGES. MANUFACTURING REQUIREMENTS PER RYAN MFG. STANDARD NO. 120.

RYAN AERONAUTICAL COMPANY, SAN DIEGO, CALIFORNIA 92112

SUPPORT PLATFORM
50 SQ FT ROL UP ASSY
TEST SET UP

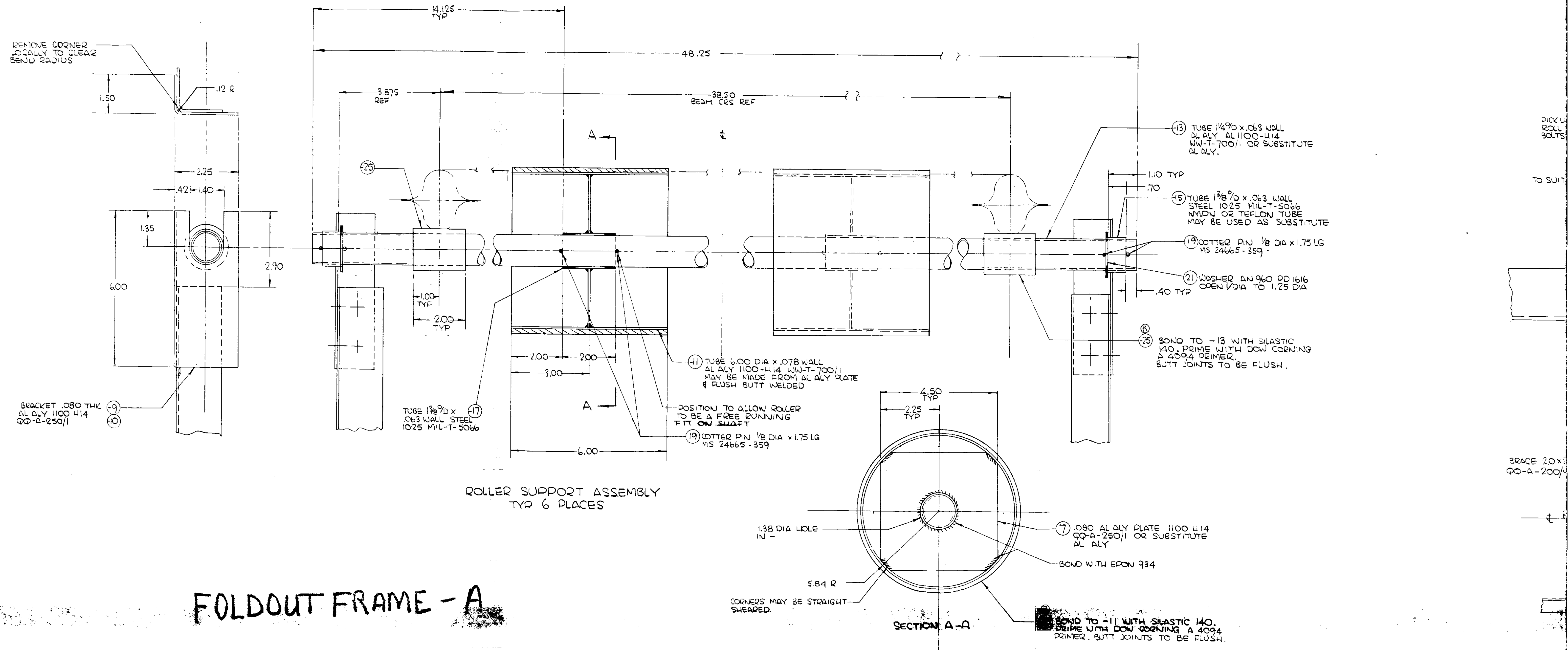
SIZE | CODE IDENT NO. 78022 | NUMBER 5K 9112
SCALE 1:6 | WEIGHT 30 | SHEET 1 OF 2

C

FOLDOUT FRAME

FOLDOUT FRAME

FOLDOUT FRAME



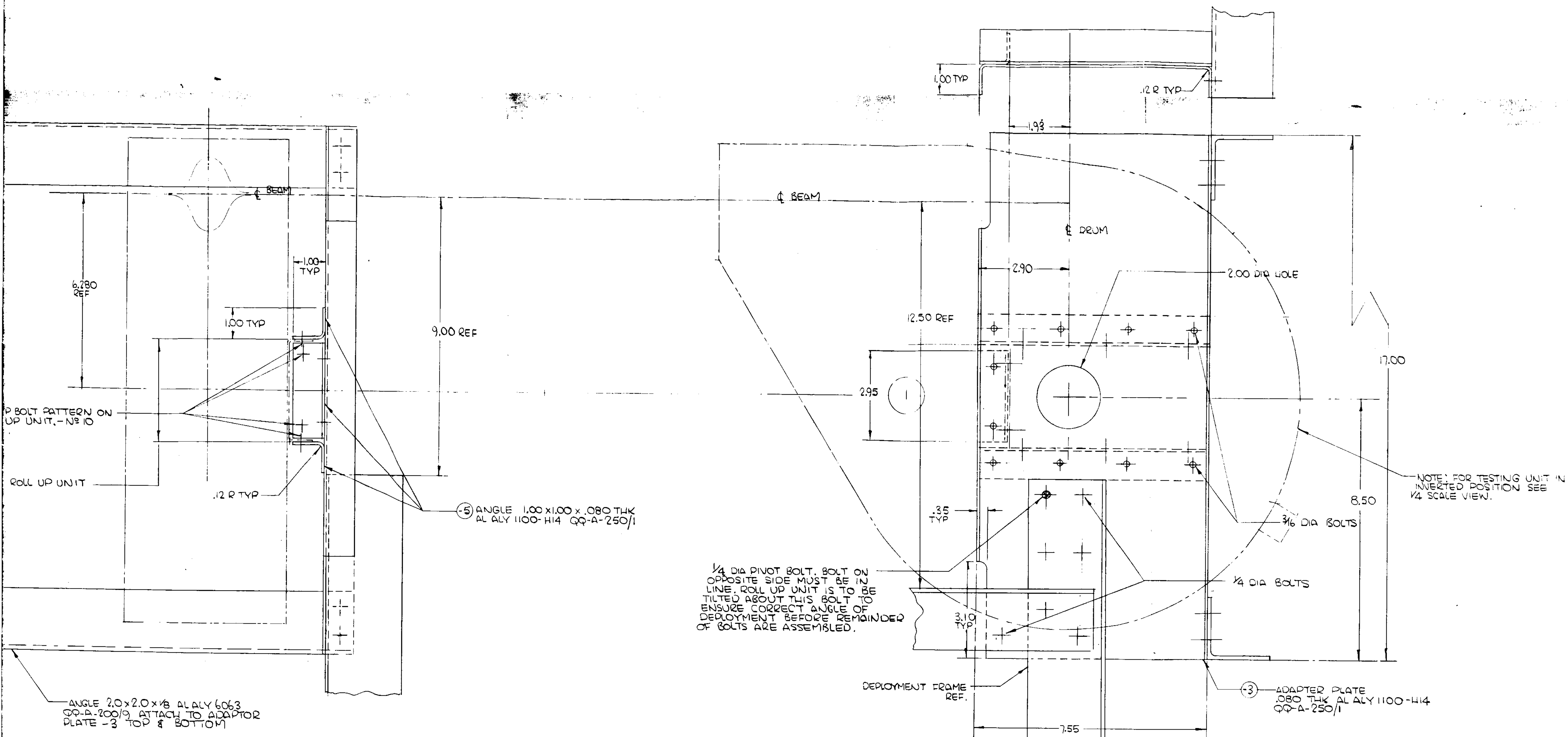
FOLDOUT FRAME - A

FOLDOUT FRAME - B

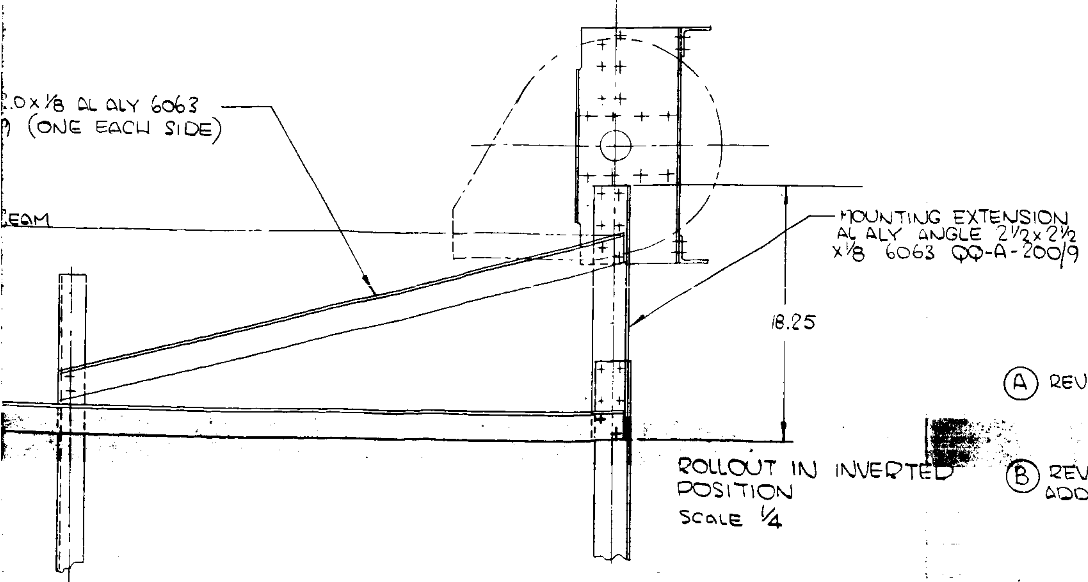
FOLDOUT FRAME

FOLDOUT FRAME

FOLDOUT FRAME



DETAIL OF ROLL-UP MOUNTING.
NOTE - REVERSE SIDE SHOWN.



ROLLOUT IN INVERTED POSITION
SCALE 1/4

NOTES:

① SUBSTITUTIONS MAY BE MADE FOR PARTS SHOWN TO FACILITATE MANUFACTURE.

② ALL PARTS INCLUDING HARDWARE ARE TO BE THOROUGHLY CLEAN & FREE FROM PAINT OR GREASE ETC.

Ⓐ REVISION. REVISED CONFIGURATION OF -3 & REMOVED -4. ADDED 2.0 x 2.0 ANGLES (2) TO TOP & BOTTOM OF OF -3
IN L.M. REVISED SIZE REQUIREMENT OF -3

Ⓑ REVISION. ADDED -23 & -25 ATTACHED TO -11 & -17
ADDED TO L.M. -23, -25 SILASTIC 140 & PRIMER A 4094

REV	QTY REQD PER ASSY	CODE IDENT	PART NUMBER	DESCRIPTION	STOCK SIZE	MATERIAL	SPECIFICATION	RYAN MATL CODE	ZONE	ITEM NO.
Ⓑ	AR			PRIMER A4094			DOW CORNING CHEMICAL Cº			
Ⓑ	AR			SILASTIC 140			DOW CORNING CHEMICAL Cº			
	12		-25	PAD	2.0 x 3.2	3/16 THK SILICONE SPONGE	AMS 3195			
	12		-23	PAD	6.0 x 19.0	3/16 THK SILICONE SPONGE	AMS 3195			
	12		-21	WASHER AN 960 PD1616						
	48		-19	COTTER PIN MS 24665-359						
	12		-17	TUBE	TUBE 1 3/8 OD x .063 THK	STEEL 1025	MIL-1-5066			
	12		-15	SPACER	TUBE 1 1/8 OD x .063 THK	STEEL .025	MIL-T-5066			
	6		-13	ROLLER	TUBE 1 1/4 OD x 4.85	.063 WALL AL ALY 1100-H14	WW-T-700/1			
	12		-11	ROLLER	6.0 DIA x 6.0 LG	TUBE .078 WALL AL ALY	WW-T-700/1 (AL ALY 1100 H14)			
	6/6		-10 / -9	BRACKET	4.0 x 6.0	.080 THK AL ALY 1100-H14	QQ-A-250/1			
	12		-7	WEB	4.5 x 4.5	.080 THK AL ALY 1100-H14	QQ-A-250/1			
	1		-5	ANGLE 1.0 x 1.0	13.5 LG	.080 THK AL ALY 1100-H14	QQ-A-250/1			
	2		-3	ADAPTER PLATE	10.0 x 17.0	.080 THK AL ALY 1100-H14	QQ-A-250/1			

MAKE FROM

LIST OF MATERIAL

RELEASE & DATE				
FINAL ASSY	NEXT ASSY	NEXT ASSEMBLY	USED ON	
QTY REQUIRED		APPLICATION		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE CHEM APPLIED OR PLATED FINISHES

TOLERANCES

LINEAR		ANGULAR
.X	±.1	EXCL OF SHEET METAL FLANGES
.XX	±.03	
.XXX	±.010	±0° 30'

PARTS TO BE FREE OF BURRS AND SHARP EDGES. MANUFACTURING REQUIREMENTS PER RYAN MFG. STANDARD NO. 130.

CONTRACT NUMBER

	SIGNATURES	DATE
DRAWN BY	L.H.W.	
GR APPD	L.H.W.	5/8/67
CHECK		
STANDARDS		
STR/WT		
PROJECT		

DESIGN ACTIVITY APPROVAL

DESIGN APPROVAL

RYAN

RYAN AERONAUTICAL COMPANY SAN DIEGO, CALIFORNIA 92112

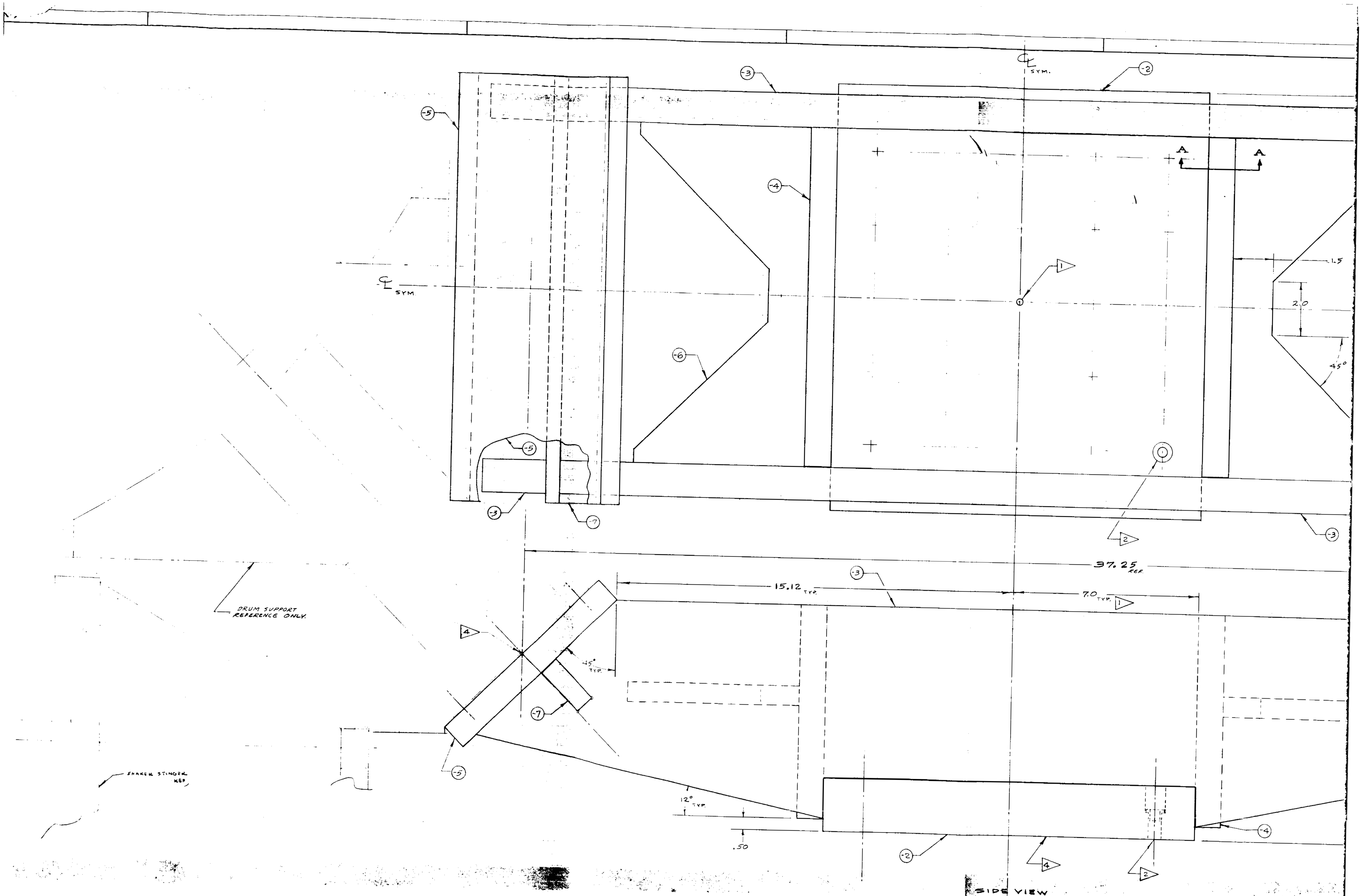
TEST FIXTURE
50 SQ FT ROLLUP
DETAILS.

SIZE	CODE IDENT NO.	NUMBER	REV SYM
	78022	SK 9112	B
SCALE	WEIGHT	SHEET 2 OF 2	

FOLDOUT FRAME - C

FOLDOUT FRAME — D

FOLDOUT FRAME - E

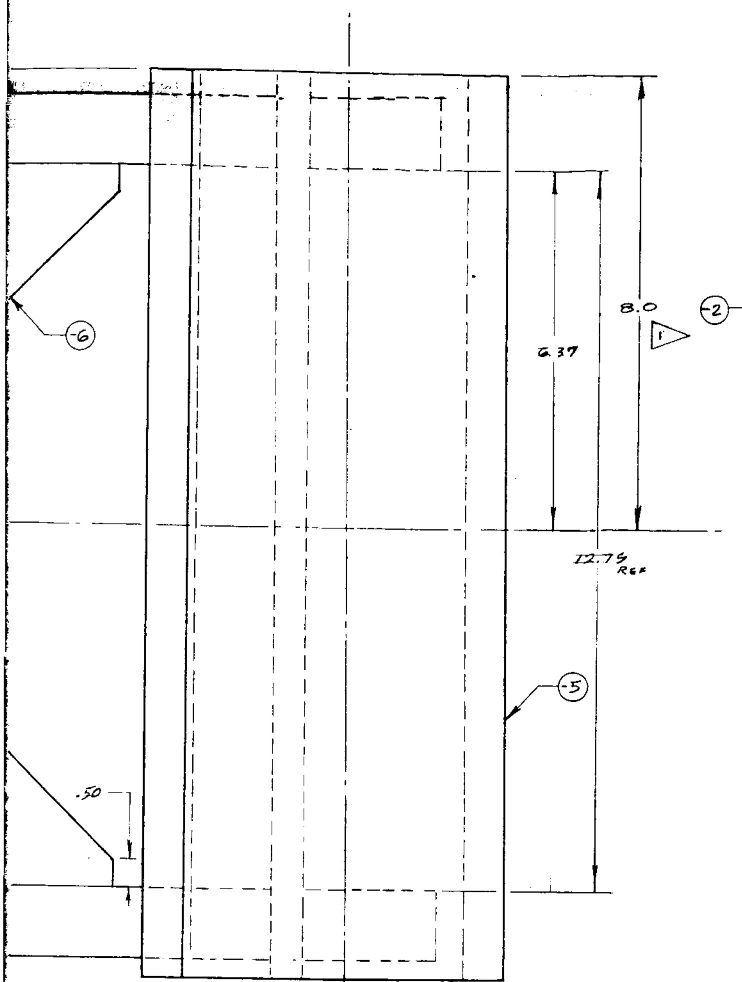


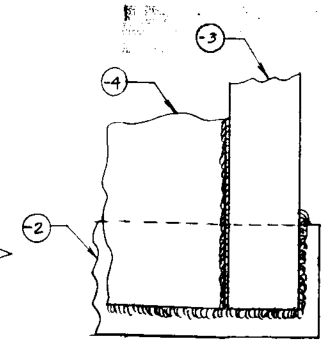
Foldout-A

FOLDOUT FRAME

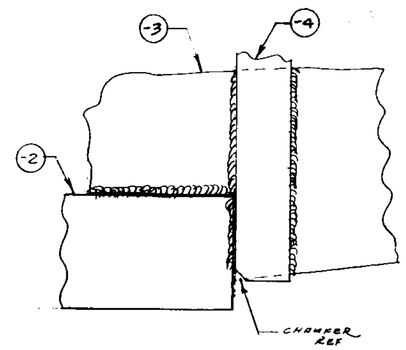
FOLDOUT FRAME

FOLDOUT FRAME-B





DETAIL A 3



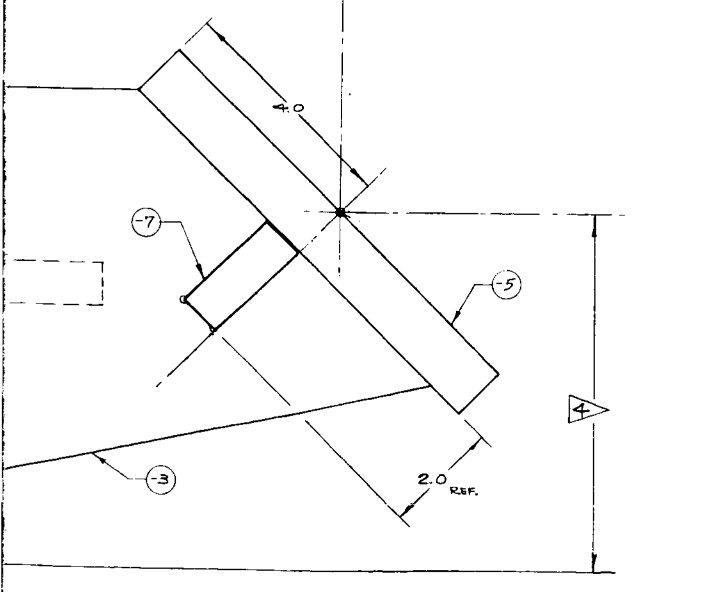
SECT. A-A 3

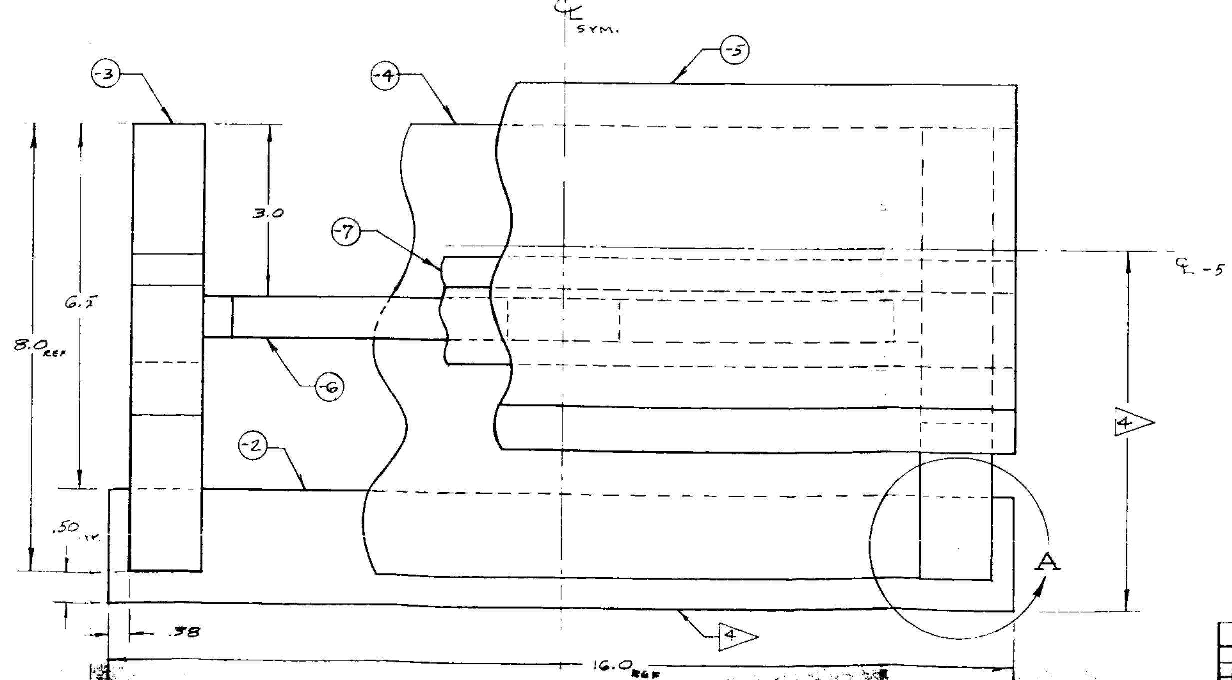
NOTES:

1. LOCATE & DRILL ⌀.250 HOLE AT INTERSECTION OF ℄s ON TOP FACE OF -2 BASE. POSITION EL-275 DRILL TEMPLATE WITH .250 TOOL PIN & DRILL (16) HOLES THRU -2. OBTAIN EL-275 TEMP. FROM ENV. LAB. DEPT 328 (RE) EXT. 8-231
2. COUNTER BORE HOLES TOP FACE -2 .75 DIA. X 1.0 DEEP. ENLARGE HOLES TO SIZE FOR PRESS FIT OF -8 BUSHINGS. INST. BUSHINGS (16). -8 BUSHINGS FURNISHED BY DEPT. 328 ENV. LAB (RE)
3. CHAMFER EDGES OF ONE INTERSECTING PART 45° X .18 FOR BETTER WELD AREA. WELD PARTS AT ALL INTERSECTIONS BOTH SIDES. (DETAIL A & SECT. A-A TYPICAL.) SECURE FULL PENETRATION BOTH PARTS. STRESS RELIEVE PER. M.P.D. 1101. TACK WELD ASSY. CHECK ALIGNMENT BEFORE FINAL WELD. MACHINE BOTTOM SURFACE OF -2 LEVEL AFTER WELDING.
4. SURFACES OF -5 SUPPORT PADS TO BE MACHINED SMOOTH & PARALELL (AT 45°) TO -2 BASE BOTTOM SURFACE WITHIN 1° (ENTIRE LENGTH) AFTER WELDING
5. SUGGESTED SOURCE MAGNEISUM MAT'L. RELIANCE STEEL & ALUM. CO. 2531 E. HARBOR DRIVE SAN DIEGO (12). CAL. PHONE 234-2104.
6. MACHINE FINISH ONLY ABOVE NOTED SURFACES. BREAK ALL EDGES.
7. DO NOT SCALE PRINT.

REVISIONS

SYM	ZONE	DESCRIPTION	DATE	APPROVED





QTY REQD PER ASSY	CODE IDENT	PART NUMBER	DESCRIPTION	STOCK SIZE	MATERIAL	SPECIFICATION	RYAN MATL CODE	ZONE	ITEM NO.
16		-8	BUSHINGS (SHOULDER)	FURNISHED BY ENV. LAB.					
2		-7	BRACE CROSS	2.0 X 16.0	.75 PLATE TOOLING	AZ-31B COMMERCIAL GRADE			
2		-6	GUSSET	13.0 X 7.0	.75				
2		-5	PAD-SUPPORT	8.0 X 16.0	1.0				
2		-4	END-BRACE	8.0 X 13.0	1.0				
2		-3	SIDE-	8.0 X 41.0	1.25				
1		-2	BASE-ATTACH	14.0 X 16.0	2.0				
		-1	VIBR. FIXTURE ASSY.						

LIST OF MATERIAL

RELEASE & DATE

QTY REQUIRED		APPLICATION	
FINAL ASSY	NEXT ASSY	NEXT ASSEMBLY	USED ON
			VIBRATION TEST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE CHEM APPLIED OR PLATED FINISHES

TOLERANCES
LINEAR: X ±.1, XX ±.03, XXX ±.010
ANGULAR: EXCL OF SHEET METAL FLANGES ±0° 30'

PARTS TO BE FREE OF BURRS AND SHARP EDGES. MANUFACTURING REQUIREMENTS PER RYAN MFG. STANDARD NO. 130.

CONTRACT NUMBER

SIGNATURES | DATE
DRAWN BY
GR APPD
CHECK
STANDARDS
STR/WT
PROJECT

DESIGN ACTIVITY APPROVAL

DESIGN APPROVAL

RYAN ELECTRONICS — RYAN AERONAUTICAL COMPANY, SAN DIEGO, CALIFORNIA 92112

FIXTURE - VIBRATION. DEPLOYABLE SOLAR PANEL TEST

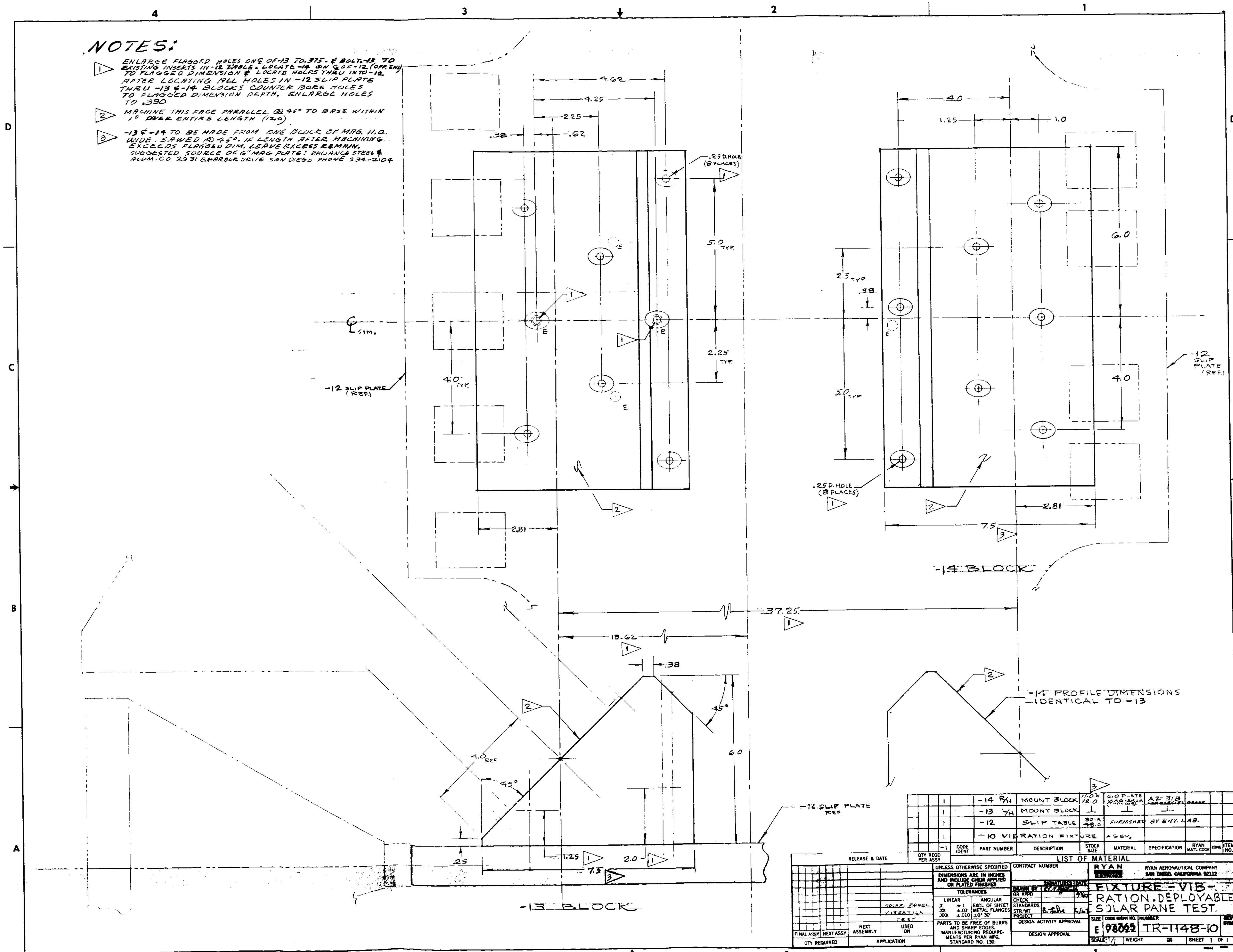
CODE IDENT NO. 78??65 — NUMBER TR-1148-1 — REV SYM

SCALE 1/1 — WEIGHT — SHEET 1 OF 1

FOLDOUT FRAME

FOLDOUT FRAME - C

FOLDOUT FRAME - D



FOLDOUT FRAME

Foldout - A

FOLDOUT FRAME

FOLDOUT FRAME - B

RYAN AERONAUTICAL COMPANY

San Diego, California 92112

RYAN ENGINEERING SPECIFICATION

208-S-003

PROCESS REQUIREMENTS FOR MODEL 208 SOLAR ARRAY -- INSTALLATION OF ACTIVE AND DUMMY SOLAR CELL SUBMODULES

Prepared By:

J. F. Callahan, Engineering Writer

Approved By:

A. J. Wellman, Project Engineer
Space Structures

REV.	AMEND.	DATE	AUTHORITY
N/C		7-25-67	
A	Revised	8-25-67	
B	Revised Pages 10	9-5-67	
	11, 12, 13 and 14		

RYAN LINDBERGH FIELD AT HARBOR DRIVE. SAN DIEGO. CALIFORNIA. 92112 • AREA CODE 714/296-6681

1.0 SCOPE

1.1 This Specification describes the installation of solar cells (submodule assemblies) bonded to a panel substrate.

1.2 This is an engineering specification to control this process at Ryan Aeronautical Company, and is effective immediately upon issue.

2.0 APPLICABLE DOCUMENTS

The following documents are used for reference and form a part of this document to the extent specified herein:

Specifications:

TT-M-261	Methyl-Ethyl-Ketone (for Use in Organic Coatings)
TT-I-735	Isopropyl Alcohol
MIL-S-23586	Silicone Rubber Compound, Room Temperature Vulcanizing

Other Publications:

Ryan Aeronautical Company:

MPD 1024	Vapor Degreasing
MPD 1061	Adhesives
MTS	Materials Test Schedule
QCM	Quality Control Manual
TMM	Test Methods Manual
W&IM	Workmanship and Inspection Manual

3.0 PRODUCT MATERIAL CONTROL

3.1 PRODUCT MATERIALS

The following materials have been evaluated by the Materials and Process Laboratories and are approved for use in accordance with the applicable specifications or drawings. Other materials conforming to the applicable specifications or drawings may be used only when evaluated and approved by the Materials and Process Laboratories.

1. Solar Cell Assembly per Spectrolab Drawing No. 015774.

2. Deployable Solar Array Panel Assembly per Ryan Drawing No. 208V013.

3. Primer, SS-4004, General Electric Company.

4. Adhesive, silicone rubber, General Electric Company No. RTV-40 per MIL-S-23586.

5. Catalyst for Item 4, General Electric Company No. Thermolite 12.

3.2 PRODUCT MATERIAL CONTROL

3.2.1 COMPONENTS

The panel substrate and solar cells shall be inspected and approved for compliance with the applicable Engineering Drawings.

3.2.2 MATERIALS

3.2.2.1 Each lot of materials shall be certified by the supplier to conform to the applicable military or Ryan specification.

3.2.2.2 Receiving Inspection, storage and retest of materials shall be accomplished in accordance with the Materials Test Schedule.

3.2.2.3 The Materials and Process Laboratories shall accomplish material testing required by the materials Test Schedule in accordance with the procedures contained in the Test Methods Manual.

3.2.2.4 Records of material testing shall be maintained in accordance with Section 5.6 of the Quality Procedures Manual.

4.0 PROCESS CONTROL

4.1 PROCESS MATERIALS

1. Methyl ethyl ketone (MEK) per TT-M-261.

2. Isopropyl Alcohol per TT-I-735.

3. RACO 2850, K-4 cleaning solvent.

4. Tape, pressure-sensitive, polyester, silicone adhesive, Minnesota Mining & Manufacturing Company No. &-9064.

5. Paper cups, unwaxed, Dixie No. 2336 or equivalent.

6. Cots, finger.

7. Applicators, cotton tipped.

8. Wipers, disposable, Kimwipes or equivalent.

9. Blades, wooden

10. Stylus, wooden.

11. Abrasive paper - Garnet 240 grit or 320 grit.

4.2 PROCESS EQUIPMENT

1. Balance, sensitivity 0.1 grams.

2. Sponge applicator - capable of depositing 0.0005 to 0.0010 thick uniform coating of SS-4004 primer.

3. Spacers, submodules.

4. Spreader, calibrated, for RTV-40, capable of depositing an adhesive layer weighing 0.03 +0.000 -0.005 pound per square foot.

5. Straight edge.

6. Template, aluminum chip arrangement.

4.2 PROCESS EQUIPMENT (Continued):

7. Vacuum system, capable of maintaining a pressure of 5 mm of mercury.

8. Weights, submodule bonding.

4.3 PROCESS PERSONNEL

Only qualified personnel who have been adequately trained and tested shall perform the operations described in this specification.

5.0 MANUFACTURING PROCESS

5.1 HANDLING PRECAUTIONS

All materials used in the manufacture of solar arrays are lightweight, fragile, and costly. Therefore, observe the following precautions when handling components.

5.1.1 Filtered submodules are subject to dislocation of the filter and delamination of bus terminal contacts when excessive pressure is applied. During cleaning, positioning and bonding operations, observe all precautions detailed in the procedures.

5.1.2 Do not allow solar cell submodules to come in contact with metallic objects. Wear finger cots whenever handling the cells to prevent their contamination.

5.1.3 The panel substrate is so lightweight that even a pencil dropped on it can cause critical damage. Therefore, the panel must be handled with extreme caution at all times and adequately supported whenever pressure is brought to bear on its surface.

5.2 BONDING OF ACTIVE SUBMODULES

5.2.1 PREPARATION OF ACTIVE SUBMODULES

5.2.1.1 All surface areas to be bonded shall be cleaned with isopropyl alcohol and Kimwipes and/or brush before priming.

5.2.1.2 Clean all the negative surface of the submodule ("N" bus bar) using isopropyl alcohol applied with cotton swab.

5.2.1.3 Using a sponge applicator, apply a uniform coat of SS-4004 primer on the faying surface of each submodule.

5.2.1.4 Allow each primed submodule to set for five (5) minutes. Using a cotton swab saturated with isopropyl alcohol, remove the excess primer from the tabs. Allow the primed submodule to dry for one hour at room temperature before usage.

5.2.2 PREPARATION OF PANEL SUBSTRATE

CAUTION: Exercise extreme care while handling the substrate assembly.

5.2.2.1 Solvent wipe the panel substrate, using clean Kimwipes saturated with MEK, and immediately wipe dry with clean, dry Kimwipes. Do not allow the solvent to evaporate on the substrate.

5.2.2.2 Carefully sand surface of substrate using #240 or #320 Garnet paper to remove gloss.

5.2.2.3 Remove sanding residue by solvent wiping the panel substrate using clean Kimwipes saturated with isopropyl alcohol and immediately wipe dry with clean, dry Kimwipes. Do not allow solvent to evaporate on the substrate. Mask-off bonding area with Y-9064 tape.

5.2.2.4 Using a sponge applicator apply a smooth uniform light pink coat of SS-4004 primer on the panel substrate. Allow to air dry at room temperature for a minimum of one hour.

5.2.2.5 The submodules shall be stored in a clean protective container until the start of the bonding operation.

5.2.3 PREPARATION AND APPLICATION OF ADHESIVE

5.2.3.1 Weigh 0.5 parts Thermolite 12 catalyst to 100 parts by weight RTV-40 adhesive and mix in an unwaxed paper cup, stirring thoroughly for not less than two (2) minutes.

NOTES:

1. Five (5) drops of Thermolite 12 equals approximately 0.1 grams.

2. A convenient adhesive formulation for this application is 12 drops of Thermolite 12 to 50 grams of RTV-40.

5.2.3.2 Record the quantity of adhesive and catalyst prepared, and the date on which it was mixed.

5.2.3.3 Deaerate the mixed material in a vacuum chamber. Maintain a pressure of three to five mm of mercury until bubbling has substantially subsided, or for ten (10) minutes maximum.

<u>CAUTION:</u> Before starting the next operation, ensure that the panel substrate is adequately supported.

5.2.3.4 Using the special calibrated spreader provided, apply a uniform film of RTV-40 adhesive approximately 0.005 inch thick on the substrate bonding area. The adhesive weight shall be 0.03 +0.000 -0.005 pound per square foot.

5.2.3.5 Retain the unused adhesive for use as a control sample for adhesive set verification with grid chart showing location.

5.2.4 <u>ACTIVE SUBMODULE INSTALLATION</u>

<u>CAUTION:</u> The submodule solar cells are fragile and easily contaminated. Keep away from metallic objects and wear finger cots when handling.

5.2.4.1 Position the first submodule, using a straight edge and submodule spacer to obtain proper alignment of the submodule.

5.2.4.2 Place the second submodule next to the spacer, then position another spacer. Continue placing the submodules and spacers alternately until all the submodules within the masked area are bonded in place.

<u>CAUTION:</u> During the next step, exercise extreme care when positioning the weights on the submodules to prevent damage of the fragile glass filters on the solar cells.

5.2.4.3 Gently place the special weights on the submodules. The weights hold the submodules in place during cure. Individual weights shall cover a row of four cells and shall have a mass of $1/2 \pm 1/10$ pound. The lower surface of the weight which contacts the cell shall be covered by a layer of teflon.

5.2.4.4 Visually inspect spacers for proper alignment and spacing of submodules. Minor variations in spacing may be corrected by carefully shifting the submodules before the silicone adhesive has set.

5.2.5 CURE AND CLEANUP

5.2.5.1 Allow the RTV-40 adhesive to cure at room temperature for one hour minimum. Check the unused portion of adhesive retained per 5.2.3.4 to verify that the material has set properly and cleanup operations may be performed.

5.2.5.2 Carefully remove weights and spacers. Do not dislodge submodules.

5.2.5.3 Remove masking tape.

5.2.5.4 Remove all excess adhesive remaining between the submodules and above the cell level, using a wood stylus or other suitable soft tool.

5.2.5.5 Using a cotton swab dampened with isopropyl alcohol, remove all visible excess primer from the substrate. Do not lift or loose submodules from the panel substrate.

5.2.5.6 Repeat Section 5.2 until all areas where active submodule bonding is specified on the Engineering Drawing have been completed.

5.2.5.7 Cure for 24 hours at room temperature.

5.2.5.8 Package for storage in the special containers provided for this purpose.

5.3 BONDING OF DUMMY SUBMODULES

5.3.1 DUMMY SUBMODULE ASSEMBLY

NOTE: Wear clean, white cotton gloves whenever handling primed aluminum chips.

5.3.1.1 Verify that the aluminum chips have been primed (pink color on faying surface). If primer is present, proceed with 5.3.1.2; if not, prime as follows:

1. Mask one surface of the chips. Prime the other surface with SS-4004.

2. Air dry the primed chips for a minimum of one hour. If submodule assembly will not immediately follow, return the chips to a clean protective container for storage. Installation of primed chips must be accomplished within 24 hours.

5.3.1.2 Assemble the aluminum chips into a submodule configuration per the Engineering Drawing, using Y-9064 pressure sensitive tape and cardboard stiffeners as required.

5.3.1.3 Store the assembled dummy submodules in a clean protective container until ready for the bonding operation.

5.3.2 INSTALLATION OF DUMMY SUBMODULES

5.3.2.1 Weigh and record the weight of the panel substrate before installing the dummy submodules.

5.3.2.2 Prepare the panel substrate per 5.2.2.

5.3.2.3 Prepare and apply adhesive per 5.2.3.

CAUTION: Before starting the next operation, ensure that the panel substrate is adequately supported.

5.3.2.4 Position the dummy submodules per 5.2.4.1 and 5.2.4.2. Place individual weights on the dummy cell rows to hold the cells in place.

5.3.2.5 Allow the RTV-40 adhesive to cure at room temperature for one hour minimum. Check the set of the adhesive before proceeding with the next step.

5.3.2.6 Remove masking tape and trim edge of adhesive.

5.3.2.7 Repeat the above portions of 5.3 until all areas where dummy submodule bonding is specified on the Engineering Drawing have been completed.

5.3.2.8 Allow the completed unit to air dry for 24 hours.

5.3.2.9 Remove the tape that was used to hold the dummy submodules together during bonding.

5.3.2.10 Remove excess adhesive and primer per 5.2.5.4 and 5.2.5.5.

5.3.2.11 Weigh and record the weight of the panel assembly after installation of the dummy submodules has been completed.

5.3.3 SPOT BONDING OF TEFLON WIRES

5.3.3.1 Determine the locations for spot bonding as required by Drawing 208V013.

5.3.3.2 Prepare the panel substrate per paragraphs 5.2.2.2 and 5.2.2.3. The surface of the wires shall be untreated.

5.3.3.3 Mask off the area to be bonded using Y-9064 tape. Position wires per 208V013 allowing specified excess between tie straps.

5.3.3.4 Prepare EPON 956 per MPD 1061. Cut glass cloth tie strips to size per 208V013.

5.3.3.5 Apply coat of EPON 956 to the area to be bonded. Place the dry cloth on the adhesive. Using a dry brush, force the adhesive into the cloth sufficiently to wet the fibers and hold loose fibers in place. Add additional EPON 956, if required.

5.3.3.6 Allow adhesive to gel at least two (2) hours. Remove tape and sand off sharp edges and loose fibers using 240 grit garnet paper. Wipe clean with isopropyl alcohol.

5.3.3.7 Unless otherwise specified by engineering drawing, the spot bonds shall be spaced at two inch intervals using a 0.20 to 0.40 inch wide bond. Additional spots shall be provided at all wiring bends and within 1.0 inch of all terminal boards.

6.0 INSPECTION

Each completed panel shall be visually inspected for compliance with the following requirements.

6.1 Excessive bonding material or loose material shall be cause for rejection. All RTV-40 shall be removed from above the cell level and in between the cells. Acceptance shall be based on a visual standard approved by Engineering.

6.2 The panel shall be examined visually for evidence of contamination which shall be cause for rejection. Contamination shall be defined as loose adhesive particles, solder flux, excess primer, excess RTV-40, loose solder balls, dust and any other foreign material.

6.3 The active submodules shall be located as specified on Ryan Engineering drawing No. 208V013.

6.4 The dummy submodules shall be neatly arranged in the general order shown on Drawing 208V013.

6.5 The active submodules shall be checked for any evidence of damage such as chips, delamination, cracks, contamination and bus bar breaks. A microscopic inspection of active cells shall be accomplished using at least a 7-power magnification. Description and location of defects shall be recorded and correlated to Drawing 208V013.

6.6 Prior to application of the SS-4004 primer the sanded surface of the substrate shall be inspected. Acceptance shall be based on visual standards approved by Engineering.

6.7 The SS-4004 primer shall be inspected for intensity and uniformity of application prior to spreading of RTV-40 or applying cell modules. Acceptance shall be based on visual standards approved by Engineering.

6.8 The top surface of dummy cells shall be completely covered by a continuous coat of paint per Drawing 208V013. Loose paint, blisters, other visual defects shall be cause for rejection. Inspection acceptance shall be based on visual standards approved by Engineering.

6.9 The front and rear surface of the substrates shall be examined to determine the presence and size of adhesive voids between cells and substrate. At least 95 per cent of the area of each cell shall be bonded. This determination shall be made visually. The use of probes is prohibited.

7.0 REPAIR OR REWORK

Spot bonding of wires shall be inspected for conformance to Drawing 208V013 and visual standards approved by Engineering.

7.1 AUTHORIZATION

7.1.1 Repair or rework to active solar cells submodules that have been improperly located, or that do not otherwise meet inspection requirements, shall be accomplished only by Material Review Board action.

7.1.2 Repair or rework to dummy submodules that have been bonded in place shall be accomplished only with prior Inspection approval on a Rework Order.

7.1.3 All other repair or rework shall be accomplished only with prior Engineering approval.

7.2 PROCEDURE FOR REPAIR OF DUMMY CELLS

Dummy cells that have been improperly bonded in place shall be repaired or reworked as follows:

7.2 PROCEDURE FOR REPAIR OF DUMMY CELLS (Continued)

1. Using lightweight nylon monofilament (fishing) line, remove the affected submodules by carefully inserting the line under each submodule and drawing the line toward the operator with a sawing motion. Exercise care not to dislodge adjacent submodules.

2. It is not necessary to remove old adhesive before applying the new unless the repair area is large enough that the total adhesive weight per square foot would exceed specified tolerances of 0.03 +0.000 -0.005 pound.

3. Apply new adhesive, allow to set for one hour, clean up and cure for 24 hours as specified in 5.3.

4. The repaired area shall meet the requirements of 6.0.

8.0 QUALITY ASSURANCE

8.1 It shall be a Departmental responsibility to adequately train operators and inspectors. The trained personnel shall then be tested by the Materials and Process Laboratories.

8.2 Ryan Inspection shall be responsible for the performance of Section 6.0.

8.3 It shall be a Departmental responsibility to ensure that process equipment meets the requirements of 4.3.

9.0 SAFETY

9.1 The solvents used in this MPD are tocix and flammable. Use these materials only in well-ventilated areas. Observe adequate fire precautions.

9.2 Avoid bare skin contact with the catalyst. Should contact occur, thoroughly wash the affected area with soap and water.

10.0 NOTES

None.